# ESA Recovery Plan for

# Lower Columbia River Coho Salmon, Lower Columbia River Chinook Salmon, Columbia River Chum Salmon, and Lower Columbia River Steelhead

**Prepared by the**
**National Marine Fisheries Service,**
**Northwest Region**

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# Disclaimer

Endangered Species Act (ESA) recovery plans delineate reasonable actions that the best available information indicates are necessary for the conservation and survival of listed species. Plans are published by the National Marine Fisheries Service (NMFS), usually with the assistance of recovery teams, state agencies, local governments, salmon recovery boards, non-governmental organizations, interested citizens of the affected area, contractors, and others. ESA recovery plans do not necessarily represent the views, official positions, or approval of any individuals or agencies involved in the plan formulation, other than NMFS. They represent the official position of NMFS only after they have been signed by the Northwest Regional Administrator. ESA recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 United States Code (USC) 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new information, changes in species status, and the completion of recovery actions.

With respect to the Lower Columbia River salmon and steelhead recovery plan, where areas of disagreement arose between a management unit plan and the species (i.e., ESU or DPS-level) plan, NMFS worked with the relevant parties to resolve the differences and in a few cases, identified in the species plan, decided not to incorporate the disputed material into the species plan.

Although an ESA recovery plan is not a regulatory document with the force of law, it provides important context for NMFS decisions under ESA section 7(a). The procedures for the section 7 consultation process are described in 50 Code of Federal Regulations (CFR) 402 and are applicable regardless of whether or not the actions are described in a recovery plan.

# Acknowledgements

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National Marine Fisheries Service
U.S. Army Corps of Engineers
U.S. Bureau of Land Management
U.S. Bureau of Indian Affairs
U.S. Bureau of Reclamation
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey

# Contents

**Acronyms and Abbreviations** ..... **xix**

**Glossary** ..... **xxiii**

**Executive Summary** ..... **ES-1**

**1. Introduction** ..... **1-1**
- 1.1 ESA Requirements ..... 1-3
- 1.2 How NMFS Intends to Use the Plan ..... 1-4
- 1.3 Geographic Setting ..... 1-4
  - 1.3.1 Topography and Ecological Zones ..... 1-5
  - 1.3.2 Climate ..... 1-6
  - 1.3.3 Land Uses and Economy ..... 1-7
  - 1.3.4 Human Population ..... 1-7
- 1.4 Species Covered by the Plan ..... 1-8
  - 1.4.1 Lower Columbia River Coho Salmon ESU ..... 1-8
  - 1.4.2 Lower Columbia River Chinook Salmon ESU ..... 1-8
  - 1.4.3 Columbia River Chum Salmon ESU ..... 1-9
  - 1.4.4 Lower Columbia River Steelhead DPS ..... 1-9
- 1.5 Context of Plan Development ..... 1-10
  - 1.5.1 Recovery Domains and Technical Recovery Teams ..... 1-11
  - 1.5.2 Management Units and Integration of Management Unit Plans ..... 1-13
    - 1.5.2.1 Washington Management Unit Recovery Plan ..... 1-14
    - 1.5.2.2 White Salmon Management Unit Recovery Plan ..... 1-15
    - 1.5.2.3 Oregon Lower Columbia Management Unit Recovery Plan ..... 1-16
    - 1.5.2.4 Relationship between Management Unit Plans and ESU-Level Plan ..... 1-16
  - 1.5.3 Challenges of Bi-State Coordination and Multiple Management Units ..... 1-16
  - 1.5.4 Challenges of Addressing Multiple ESUs/DPSs in a Single Recovery Plan ..... 1-18
  - 1.5.5 Relationship to Other Processes ..... 1-19
    - 1.5.5.1 Willamette-Lower Columbia ESA Executive Committee ..... 1-19
    - 1.5.5.2 Northwest Power and Conservation Council Subbasin Plans ..... 1-19
    - 1.5.5.3 2008 FCRPS Biological Opinion and 2010 Supplement ..... 1-20
    - 1.5.5.4 Columbia River Hatchery Scientific Review Group (HSRG) ..... 1-21
    - 1.5.5.5 State-Level Planning Processes ..... 1-22
- 1.6 Tribal Treaty and Trust Responsibilities ..... 1-24

**2. Defining Viability for Salmon and Steelhead** ..... **2-1**
- 2.1 ESU/DPS Biological Structure ..... 2-1
  - 2.1.1 Evolutionarily Significant Units and Distinct Population Segments ..... 2-2
  - 2.1.2 Strata ..... 2-2
  - 2.1.3 Independent Populations ..... 2-3
- 2.2 Viable Salmonid Populations ..... 2-3

2.2.1 Abundance and Productivity ....2-3
2.2.2 Spatial Structure and Diversity ....2-4
2.3 Critical Habitat ....2-5
2.4 WLC TRT Biological Viability Criteria ....2-7
2.4.1 Background ....2-7
2.4.2 Viability Criteria Technical Reports ....2-8
2.4.3 TRT ESU-Level Viability Criteria ....2-9
2.4.3.1 Defining ESU-Level Viability ....2-9
2.4.3.2 ESU-Level Recovery Strategy Guidance ....2-9
2.4.4 TRT Stratum-Level Viability Criteria ....2-10
2.4.4.1 Criterion 1: How Many Populations in the Stratum Should Be Viable? ....2-10
2.4.4.2 Criterion 2: Which Populations in the Stratum Should Be Viable? ....2-11
2.4.5 TRT Population-Level Viability Criteria ....2-12
2.4.6 Population Size ....2-14
2.5 WLC TRT Approach to Assessing Population Status ....2-15

**3. Recovery Goals and Delisting Criteria ....3-1**
3.1 Management Unit Plan Recovery Goals ....3-2
3.1.1 Plan Purposes and Broad Sense Recovery Goals ....3-2
3.1.1.1 Washington Management Unit Recovery Plan ....3-2
3.1.1.2 Oregon Lower Columbia Management Unit Recovery Plan ....3-3
3.1.1.3 White Salmon Management Unit Recovery Plan ....3-4
3.1.2 Management Unit Plan Biological Recovery Goals ....3-4
3.1.3 Recovery Scenarios for ESU/DPS ....3-4
3.2 NMFS Delisting Criteria ....3-8
3.2.1 Biological Criteria ....3-8
3.2.2 Threats Criteria ....3-10
3.2.3 Delisting Criteria Conclusion ....3-14
3.3 Achieving Broad Sense Goals after Delisting ....3-15

**4. Regional Limiting Factors and Strategies ....4-1**
4.1 Tributary Habitat ....4-1
4.1.1 Tributary Habitat Limiting Factors and Threats ....4-2
4.1.2 Regional Strategy for Tributary Habitat ....4-5
4.2 Estuary Habitat ....4-9
4.2.1 Estuary Habitat Limiting Factors and Threats ....4-10
4.2.2 Regional Strategy for Estuary Habitat ....4-12
4.3 Hydropower ....4-13
4.3.1 Hydropower Limiting Factors and Threats ....4-14
4.3.1.1 Reservoir-Related or Structural Impacts ....4-14
4.3.1.2 Flow-Related Impacts ....4-15
4.3.2 Regional Hydropower Strategy ....4-17
4.4 Hatcheries ....4-19
4.4.1 Hatchery Limiting Factors and Threats ....4-21
4.4.1.1 Genetic Effects ....4-21
4.4.1.2 Competition (Density-Dependent Mortality) and Predation ....4-22
4.4.1.3 Other Effects: Disease Transmission, Passage Blockages, Water

Withdrawals, and Mixed Stock Harvest ....4-23
4.4.2 Regional Hatchery Strategy ....4-23
4.5 Harvest ....4-26
4.5.1 Harvest Limiting Factors and Threats ....4-30
4.5.1.1 Harvest Mortality ....4-30
4.5.1.2 Selection for Size, Age, Distribution, or Timing ....4-30
4.5.1.3 Nutrient Supply and Carrying Capacity ....4-31
4.5.2 Regional Harvest Strategy ....4-31
4.6 Ecological Interactions ....4-33
4.6.1 Limiting Factors and Threats Related to Ecological Interactions ....4-33
4.6.1.1 Predation ....4-34
4.6.1.2 Competition ....4-35
4.6.1.3 Disease Transfer ....4-37
4.6.2 Regional Ecological Interactions Strategy ....4-37
4.6.3 Effects of Recovery Actions on Other Species ....4-37
4.6.3.1 Bull Trout ....4-40
4.6.3.2 Eulachon ....4-41
4.6.3.3 Green Sturgeon ....4-41
4.6.3.4 Southern Resident Killer Whale ....4-42
4.6.3.5 Stellar Sea Lion ....4-43
4.7 Climate Change ....4-43
4.7.1 Climate Change Limiting Factors and Threats ....4-43
4.7.1.1 Information Sources ....4-44
4.7.1.2 Effects of Climate Change on LCR Salmon and Steelhead ....4-45
4.7.2 Regional Climate Change Strategy ....4-52
4.7.2.1 Mitigation Strategy ....4-52
4.7.2.2 Adaptation Strategy ....4-52
4.8 Human Population Growth ....4-56
4.8.1 Limiting Factors and Threats Related to Human Population Growth ....4-56
4.8.2 Regional Strategy for Human Population Growth ....4-57
4.9 Summary ....4-59

**5. Overall Approach to Species Recovery Analyses ....5-1**
5.1 Baseline Population Status ....5-2
5.1.1 Oregon Approach to Assessing Baseline Status ....5-3
5.1.2 Washington Approach to Assessing Baseline Status ....5-4
5.1.3 White Salmon Approach to Assessing Baseline Status ....5-5
5.1.4 Differences in Status Assessment Methods ....5-5
5.2 Target Status ....5-6
5.2.1 Recovery Scenario ....5-6
5.2.2 Conservation Gaps ....5-6
5.3 Limiting Factors and Threats ....5-7
5.4 NMFS Limiting Factors Crosswalk ....5-9
5.5 Baseline Threat Impacts ....5-9
5.5.1 Oregon Approach to Quantifying Baseline Threat Impacts ....5-10
5.5.2 Washington Approach to Quantifying Baseline Threat Impacts ....5-11
5.5.3 White Salmon Approach to Quantifying Baseline Threat Impacts ....5-12
5.6 Threat Reduction Scenarios ....5-12

5.6.1 Oregon's Threat Reduction Scenarios ..... 5-13
5.6.2 Washington's Threat Reduction Scenarios and Interim Benchmarks ..... 5-14
5.6.3 White Salmon Threat Reduction Scenarios ..... 5-14
5.7 Recovery Strategies and Actions ..... 5-15
5.7.1 Oregon Approach to Developing Recovery Strategies and Actions ..... 5-15
5.7.2 Washington Approach to Developing Recovery Strategies and Actions ..... 5-16
5.7.3 White Salmon Approach to Developing Recovery Strategies and Actions ..... 5-17
5.8 Analysis of Actions ..... 5-17
5.9 Research, Monitoring, and Evaluation ..... 5-19
5.10 NMFS 2011 Status Assessments ..... 5-20

**6. Lower Columbia River Coho Salmon ..... 6-1**
6.1 Coho Salmon Biological Background ..... 6-1
6.1.1 Coho Salmon Life History and Habitat ..... 6-1
6.1.2 Historical Distribution and Population Structure of LCR Coho Salmon ..... 6-3
6.2 Baseline Population Status of LCR Coho Salmon ..... 6-5
6.3 Target Status and Conservation Gaps for Coho Salmon Populations ..... 6-7
6.4 Limiting Factors and Threats for LCR Coho Salmon ..... 6-12
6.4.1 Tributary Habitat Limiting Factors ..... 6-16
6.4.2 Estuary Habitat Limiting Factors ..... 6-18
6.4.3 Hydropower Limiting Factors ..... 6-19
6.4.4 Harvest Limiting Factors ..... 6-20
6.4.5 Hatchery-Related Limiting Factors ..... 6-21
6.4.6 Predation Limiting Factors ..... 6-21
6.5 Baseline Threat Impacts and Reduction Targets ..... 6-22
6.6 ESU Recovery Strategy for LCR Coho Salmon ..... 6-29
6.6.1 Strategy Summary ..... 6-29
6.6.2 Tributary Habitat Strategy ..... 6-30
6.6.3 Estuary Habitat Strategy ..... 6-33
6.6.4 Hydropower Strategy ..... 6-34
6.6.5 Harvest Strategy ..... 6-37
6.6.6 Hatchery Strategy ..... 6-39
6.6.7 Predation Strategy ..... 6-41
6.6.8 Critical Uncertainties ..... 6-41
6.7 Delisting Criteria Conclusion for LCR Coho Salmon ..... 6-42

**7. Lower Columbia River Chinook Salmon ..... 7-1**
7.1 Chinook Salmon Biological Background ..... 7-1
7.1.1 Life History and Habitat ..... 7-1
7.1.1.1 Spring Chinook Salmon Life History ..... 7-1
7.1.1.2 Fall Chinook ("Tule") Salmon Life History ..... 7-3
7.1.1.3 Late-Fall ("Bright") Chinook Salmon Life History ..... 7-3
7.1.2 Historical Distribution and Population Structure of LCR Chinook Salmon ..... 7-4
7.2 Baseline Population Status of LCR Chinook Salmon ..... 7-6

7.2.1 Baseline Status of LCR Spring Chinook Salmon ....7-7
7.2.2 Baseline Status of LCR Tule Fall Chinook Salmon....7-8
7.2.3 Baseline Status of LCR Late-Fall (Bright) Chinook Salmon....7-11
7.3 Target Status and Conservation Gaps for Chinook Salmon Populations....7-12
7.4 Spring Chinook Salmon Analysis: Limiting Factors, Threat Reductions, and Recovery Strategies....7-19
7.4.1 Spring Chinook Limiting Factors....7-19
7.4.1.1 Tributary Habitat Limiting Factors....7-23
7.4.1.2 Estuary Habitat Limiting Factors....7-25
7.4.1.3 Hydropower Limiting Factors....7-26
7.4.1.4 Harvest Limiting Factors....7-27
7.4.1.5 Hatchery-Related Limiting Factors....7-28
7.4.1.6 Predation Limiting Factors....7-28
7.4.2 Spring Chinook Salmon Baseline Threat Impacts and Threat Reduction Targets....7-28
7.4.3 Spring Chinook Salmon Recovery Strategy....7-34
7.4.3.1 Strategy Summary....7-34
7.4.3.2 Tributary Habitat Strategy....7-35
7.4.3.3 Estuary Habitat Strategy....7-37
7.4.3.4 Hydropower Strategy....7-38
7.4.3.5 Harvest Strategy....7-41
7.4.3.6 Hatchery Strategy....7-42
7.4.3.7 Predation Strategy....7-46
7.4.3.8 Critical Uncertainties....7-46
7.5 Fall Chinook Salmon Analysis: Limiting Factors, Threat Reductions, and Recovery Strategies....7-48
7.5.1 Fall Chinook Limiting Factors....7-48
7.5.1.1 Tributary Habitat Limiting Factors....7-53
7.5.1.2 Estuary Habitat Limiting Factors....7-55
7.5.1.3 Hydropower Limiting Factors....7-56
7.5.1.4 Harvest Limiting Factors....7-57
7.5.1.5 Hatchery-Related Limiting Factors....7-57
7.5.1.6 Predation Limiting Factors....7-58
7.5.2 Fall Chinook Salmon Baseline Threat Impacts and Reduction Targets....7-58
7.5.3 Fall Chinook Salmon Recovery Strategy....7-64
7.5.3.1 Strategy Summary....7-64
7.5.3.2 Tributary Habitat Strategy....7-66
7.5.3.3 Estuary Habitat Strategy....7-69
7.5.3.4 Hydropower Strategy....7-70
7.5.3.5 Harvest Strategy....7-73
7.5.3.6 Hatchery Strategy....7-75
7.5.3.7 Predation Strategy....7-78
7.5.3.8 Critical Uncertainties....7-78
7.6 Late-Fall Chinook Salmon Analysis: Limiting Factors, Threat Reductions, and Recovery Strategies....7-79
7.6.1 Late-Fall Chinook Salmon Limiting Factors....7-79
7.6.1.1 Tributary Habitat Limiting Factors....7-82

7.6.1.2 Estuary Habitat Limiting Factors ....7-83
7.6.1.3 Hydropower Limiting Factors ....7-84
7.6.1.4 Harvest Limiting Factors ....7-84
7.6.1.5 Hatchery-Related Limiting Factors ....7-84
7.6.1.6 Predation Limiting Factors ....7-85
7.6.2 Late-Fall Chinook Salmon Baseline Threat Impacts and Reduction Targets ....7-85
7.6.3 Late-Fall Chinook Salmon Recovery Strategy ....7-89
7.6.3.1 Strategy Summary ....7-89
7.6.3.2 Tributary and Estuarine Habitat Strategy ....7-89
7.6.3.3 Hydropower Strategy ....7-89
7.6.3.4 Harvest Strategy ....7-90
7.6.3.5 Hatchery Strategy ....7-90
7.6.3.6 Predation Strategy ....7-90
7.6.3.7 Critical Uncertainties ....7-90
7.7 Delisting Criteria Conclusion for LCR Chinook Salmon ....7-91

**8. Columbia River Chum Salmon ....8-1**
8.1 Chum Salmon Biological Background ....8-1
8.1.1 Chum Salmon Life History and Habitat ....8-1
8.1.2 Historical Distribution and Population Structure of Columbia River Chum Salmon ....8-2
8.2 Baseline Population Status of Columbia River Chum Salmon ....8-4
8.3 Target Status and Conservation Gaps for Columbia River Chum Salmon ....8-5
8.4 Limiting Factors and Threats for Columbia River Chum Salmon ....8-10
8.4.1 Tributary Habitat Limiting Factors ....8-14
8.4.2 Estuary Habitat Limiting Factors ....8-16
8.4.3 Hydropower Limiting Factors ....8-17
8.4.4 Harvest Limiting Factors ....8-17
8.4.5 Hatchery-Related Limiting Factors ....8-18
8.4.6 Predation Limiting Factors ....8-18
8.5 Baseline Threat Impacts and Reduction Targets ....8-19
8.6 ESU Recovery Strategy for Columbia River Chum Salmon ....8-24
8.6.1 Strategy Summary ....8-24
8.6.2 Tributary Habitat Strategy ....8-25
8.6.3 Estuary Habitat Strategy ....8-29
8.6.4 Hydropower Strategy ....8-30
8.6.5 Harvest Strategy ....8-31
8.6.6 Hatchery Strategy ....8-32
8.6.7 Predation Strategy ....8-33
8.6.8 Critical Uncertainties ....8-33
8.7 Delisting Criteria Conclusion for Columbia River Chum Salmon ....8-35

**9. Lower Columbia River Steelhead ....9-1**
9.1 Steelhead Biological Background ....9-1
9.1.1 Steelhead Life History and Habitat ....9-1
9.1.2 Historical Distribution and Population Structure of LCR Steelhead ....9-4
9.2 Baseline Population Status of LCR Steelhead ....9-6
9.2.1 Baseline Status of LCR Summer Steelhead ....9-6

9.2.2 Baseline Status of LCR Winter Steelhead ....9-7
9.3 Target Status and Conservation Gaps for Steelhead Populations ....9-9
9.4 Limiting Factors and Threats for LCR Steelhead....9-15
9.4.1 Tributary Habitat Limiting Factors ....9-22
9.4.2 Estuary Habitat Limiting Factors....9-23
9.4.3 Hydropower Limiting Factors ....9-24
9.4.4 Harvest Limiting Factors....9-25
9.4.5 Hatchery-Related Limiting Factors ....9-26
9.4.6 Predation ....9-27
9.5 Baseline Threat Impacts and Threat Reduction Targets....9-27
9.6 DPS Recovery Strategy for LCR Steelhead....9-34
9.6.1 Strategy Summary....9-34
9.6.2 Tributary Habitat Strategy....9-36
9.6.3 Estuary Habitat Strategy ....9-39
9.6.4 Hydropower Strategy....9-39
9.6.5 Harvest Strategy ....9-42
9.6.6 Hatchery Strategy....9-43
9.6.7 Predation Strategy....9-44
9.6.8 Critical Uncertainties ....9-44
9.7 Delisting Criteria Conclusion for LCR Steelhead ....9-45

**10. Adaptive Management and Research, Monitoring, and Evaluation....10-1**
10.1 Overview of Adaptive Management and RME Needs....10-1
10.2 Guidance for Adaptive Management and RME ....10-3
10.2.1 Adaptive Management for ESA-Listed Salmon and Steelhead Recovery Decision Framework and Monitoring Guidance....10-3
10.2.2 Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead ....10-5
10.2.3 Other RME Guidance ....10-7
10.2.3.1 Columbia River Basin Fish and Wildlife Program 2009 Amendments ....10-7
10.2.3.2 Recommendation for Implementing RME for the 2008 NOAA Fisheries FCRPS Biological Opinion ....10-7
10.2.3.3 Salmon Monitoring Advisor....10-8
10.3 RME Plans for the Washington, Oregon, and White Salmon Management Unit Plans ....10-8
10.3.1 Washington Management Unit....10-8
10.3.1.1 Biological Status Monitoring....10-9
10.3.1.2 Habitat Status Monitoring ....10-9
10.3.1.3 Implementation and Compliance Monitoring....10-9
10.3.1.4 Action Effectiveness Monitoring ....10-9
10.3.1.5 Research Needs ....10-10
10.3.1.6 Data Management....10-11
10.3.1.7 Programmatic Evaluation....10-11
10.3.2 Oregon Management Unit....10-11
10.3.2.1 Biological Status Monitoring....10-11
10.3.2.2 Monitoring Related to Listing Factors ....10-12
10.3.3 White Salmon Management Unit ....10-14
10.4 Estuary Module RME ....10-14

10.5 RME in Biological Opinions and Records of Decision....10-15
10.6 Regional Coordination Efforts....10-15
10.6.1 Anadromous Salmonid Monitoring Strategy (ASMS)....10-17
10.6.2 PNAMP Integrated Status and Trend Monitoring Demonstration Project....10-19
10.7 Additional Needs for RME in the Lower Columbia....10-19
10.7.1 Integrated RME Program....10-20
10.7.2 Data Management and Integration....10-20
10.8 Research on Critical Uncertainties....10-20
10.9 RME and ESA 5-Year Status Reviews....10-21

**11. Implementation and Coordination....11-1**
11.1 NMFS' Vision for Recovery Implementation....11-1
11.2 Prioritizing Recovery Actions....11-2
11.2.1 Prioritizing Populations....11-2
11.2.2 Geographic Priorities....11-3
11.2.3 Prioritizing Actions....11-4
11.3 Organizational Structure and Implementation Roles and Responsibilities....11-5
11.3.1 Subdomain Level: Columbia River Plan Implementation Steering Committee....11-6
11.3.1.1 Organization/Membership....11-7
11.3.1.2 Operations....11-7
11.3.1.3 Areas of Focus....11-7
11.3.2 Management Unit Level....11-9
11.3.2.1 Oregon....11-10
11.3.2.2 Washington....11-13
11.3.2.3 White Salmon....11-16
11.3.3 NMFS' Role....11-16
11.3.3.1 ESA Responsibilities....11-17
11.3.3.2 LC Steering Committee Convening Partner....11-17
11.3.4 Columbia River Estuary....11-17
11.4 Implementation Time Frames....11-18
11.4.1 Oregon Management Unit Plan....11-18
11.4.2 Washington Management Unit Plan....11-19
11.4.3 White Salmon Management Unit Plan....11-19
11.4.4 Columbia River Estuary Recovery Plan Module....11-19
11.5 NMFS Time Frame....11-20

**12. Site-Specific Management Actions and Cost Estimates....12-1**
12.1 Site-Specific Management Actions....12-1
12.1.1 Washington Management Unit Plan....12-6
12.1.2 Oregon Management Unit Plan....12-6
12.1.3 White Salmon Management Unit Plan....12-7
12.1.4 Estuary Module....12-8
12.2 Cost Estimates....12-8
12.2.1 Washington Management Unit Plan....12-10
12.2.2 Oregon Management Unit Plan....12-11
12.2.3 White Salmon Management Unit Plan....12-12
12.2.4 Estuary Module....12-13

12.3 Time Estimate .....12-14

**13. References.....13-1**

## Appendices

A Oregon Management Unit Plan
(see http://www.dfw.state.or.us/fish/CRP/lower_columbia_plan.asp)

B Washington Management Unit Plan
(see http://www.lcfrb.gen.wa.us/Recovery%20Plans/RP%20Frontpage.htm)

C White Salmon Management Unit Plan (see
http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/lower_columbia_river/lower_columbia_river_recovery_plan_for_salmon_steelhead.html)

D Estuary Recovery Plan Module (see
http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/recovery_plans_supporting_documents.html)

E Hydropower Module (see
http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/recovery_plans_supporting_documents.html)

F Ecological Interactions White Paper

G Habitat Concerns Data Dictionary

H Limiting Factors Crosswalk and Methodology

## Tables

ES-1 Population-Level Probability of Persistence, Extinction Risk, and Status ..... ES-5
ES-2 Summary of Cost Estimates ..... ES-9
ES-3 Subbasins Targeted to Support Three or More Primary Populations ..... ES-12
ES-4 Baseline and Target Status of LCR Coho Salmon Populations ..... ES-17
ES-5 Prevalent Primary Limiting Factors for Coho Salmon during Baseline Period ..... ES-19
ES-6 Baseline and Target Status of LCR Chinook Salmon Populations ..... ES-21
ES-7 Prevalent Primary Limiting Factors for Spring Chinook Salmon during Baseline Period ..... ES-23
ES-8 Prevalent Primary Limiting Factors for Fall Chinook Salmon during Baseline Period ..... ES-25
ES-9 Prevalent Primary Limiting Factors for Late-fall Chinook Salmon during Baseline Period ..... ES-27
ES-10 Baseline and Target Status of Columbia River Chum Salmon Populations .... ES-28
ES-11 Prevalent Primary Limiting Factors for Chum Salmon during Baseline Period ..... ES-29

ES-12 Baseline and Target Status of LCR Steelhead Populations..... ES-32
ES-13 Prevalent Primary Limiting Factors for Winter Steelhead during Baseline Period..... ES-34
ES-14 Prevalent Primary Limiting Factors for Summer Steelhead during Baseline Period..... ES-34
1-1 Lower Columbia Subbasins, by State and Ecological Zone .....1-6
2-1 Population Viability Categories, Corresponding to 100-Year Extinction Risk...2-11
2-2 Stratum-Level Extinction Risk Associated with Population Risk .....2-11
2-3 Viability Criteria and Guidelines from the Willamette-Lower Columbia Technical Recovery Team.....2-13
2-4 Population Scores and Corresponding Probability of Persistence (or Extinction).....2-16
3-1 Recovery Scenarios for LCR Chinook, Columbia River Chum, LCR Steelhead, and LCR Coho.....3-6
4-1 Common Tributary Habitat Limiting Factors and Threats .....4-4
4-2 Representative Actions to Address Limiting Factors Affecting Most Populations.....4-6
4-3 Subbasins Targeted to Support Three or More Primary Populations .....4-8
4-4 Estimated Average Survival Rates of Lower Columbia Salmon and Steelhead Passing Bonneville Dam .....4-18
4-5 Projected Survival Improvements for Lower Columbia Salmon and Steelhead from Actions to Reduce Predation in the Estuary .....4-19
4-6 Hatchery Releases of Salmon and Steelhead in the Lower Columbia River, 2011 .....4-20
4-7 Fisheries Affecting Lower Columbia ESUs .....4-28
4-8 Estimated Harvest Rates on Lower Columbia River Salmon and Steelhead Before and After Listing.....4-29
4-9 Federally Listed Fish and Wildlife Species in the Lower Columbia Recovery Planning Area .....4-40
4-10 Summary of Expected Climate Effects on Pacific Northwest ESUs.....4-50
4-11 Strategies and Representative Actions to Address Climate Change Impacts ....4-54
4-12 Representative Actions and Strategies to Mitigate for Human Population Growth.....4-58
5-1 Population Scores and Corresponding Probability of Persistence (or Extinction).....5-3
5-2 Key Differences in Status Assessment Methodologies .....5-6
6-1 Key Habitat for Coho Salmon, by Life Stage.....6-2
6-2 Historical LCR Coho Salmon Populations.....6-4
6-3 Artificial Propagation Programs for LCR Coho Salmon .....6-5
6-4 Baseline and Target Persistence Probability and Abundance of LCR Coho Salmon Populations.....6-10
6-5 Baseline Limiting Factors and Threats Affecting LCR Coho Salmon: Stratum-Level Summary .....6-13
6-6 Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Coho Salmon Populations .....6-26
6-7 Coho Salmon Recovery Scenario Scores Relative to WLC TRT's Viability Criteria .....6-43
7-1 Key Habitat for Fall and Spring Chinook Salmon, by Life Stage .....7-2

7-2 Historical LCR Chinook Salmon Populations ..... 7-5
7-3 Artificial Propagation Programs Included in the LCR Chinook Salmon ESU ..... 7-6
7-4 Baseline and Target Persistence Probability and Abundance of LCR Chinook Salmon Populations ..... 7-16
7-5 Baseline Limiting Factors and Threats Affecting LCR Spring Chinook Salmon: Stratum-Level Summary ..... 7-20
7-6 Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Spring Chinook Salmon Populations ..... 7-32
7-7 Baseline Limiting Factors and Threats Affecting LCR Fall Chinook Salmon: Stratum-Level Summary ..... 7-50
7-8 Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Fall Chinook Salmon Populations ..... 7-62
7-9 Baseline Limiting Factors and Threats Affecting LCR Late-Fall Chinook Salmon: Stratum-Level Summary ..... 7-81
7-10 Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Late-fall Chinook Salmon Populations ..... 7-88
7-11 LCR Chinook Salmon Recovery Scenario Scores Relative to WLC TRT Viability Criteria ..... 7-92
8-1 Historical Columbia River Chum Salmon Populations ..... 8-3
8-2 Baseline and Target Persistence Probability and Abundance of Columbia River Chum Salmon Populations ..... 8-8
8-3 Baseline Limiting Factors and Threats Affecting Columbia River Chum Salmon: Stratum-Level Summary ..... 8-12
8-4 Impacts of Potentially Manageable Threat, and Impact Reduction Targets Consistent with Recovery of Columbia River Chum Salmon (Washington Populations Only) ..... 8-22
8-5 Chum Salmon Recovery Scenario Scores Relative to WLC TRT's Viability Criteria ..... 8-36
9-1 Key Habitat for Steelhead, by Life Stage ..... 9-3
9-2 Historical LCR Steelhead Populations ..... 9-5
9-3 Artificial Propagation Programs for LCR Steelhead ..... 9-6
9-4 Baseline and Target Persistence Probability and Abundance of LCR Steelhead Populations ..... 9-12
9-5 Baseline Limiting Factors and Threats Affecting LCR Winter Steelhead: Stratum-Level Summary ..... 9-16
9-6 Baseline Limiting Factors and Threats Affecting LCR Summer Steelhead: Stratum-Level Summary ..... 9-19
9-7 Impacts of Potentially Manageable Impacts of Threats and Impact Reduction Targets Consistent with Recovery of LCR Steelhead Populations ..... 9-31
9-8 Steelhead Recovery Scenario Scores Relative to WLC TRT Viability Criteria ..... 9-46
12-1 Representative Recovery Actions ..... 12-2
12-2 Summary of Cost Estimates ..... 12-10

## Figures

ES-1 Conservation Gaps for LCR Coho Salmon Populations ..... ES-18
ES-2 Conservation Gaps for LCR Spring Chinook Salmon Populations ..... ES-22
ES-3 Conservation Gaps for LCR Fall and Late-Fall Chinook

| | | |
|---|---|---|
| | Salmon Populations | ES-22 |
| ES-4 | Conservation Gaps for Columbia River Chum Salmon Populations | ES-29 |
| ES-5 | Conservation Gaps for LCR Winter Steelhead Populations | ES-33 |
| ES-6 | Conservation Gaps for LCR Summer Steelhead Populations | ES-33 |
| 1-1 | NMFS Northwest Region Recovery Domains | 1-12 |
| 1-2 | Management Units of the Willamette-Lower Columbia Recovery Domain | 1-14 |
| 2-1 | Hierarchical Levels of Salmonid Species Structure for ESU/DPS Recovery Planning | 2-2 |
| 4-1 | Changes in Annual Columbia River Flow | 4-16 |
| 4-2 | Projected Average Monthly Stream Flow (cfs) for the White Salmon and Kalama Rivers and the Mainstem Columbia River at Bonneville Dam | 4-46 |
| 4-3 | Preliminary Maps of Predicted Hydrologic Regime for 1970-1999 and 2070-2099 | 4-47 |
| 5-1 | Sample "Diamond Graph" Showing Populations with Different Distributions of Extinction Risk (Inverse of Persistence Probability) | 5-4 |
| 6-1 | Life Cycle of Lower Columbia River Coho Salmon | 6-2 |
| 6-2 | Baseline Status of Historical LCR Coho Salmon Populations | 6-7 |
| 6-3 | Conservation Gaps for LCR Coho Salmon Populations: Difference between Baseline and Target Status | 6-9 |
| 7-1 | Life Cycle of Lower Columbia River Spring Chinook Salmon | 7-2 |
| 7-2 | Life Cycle of Lower Columbia River Fall Chinook Salmon | 7-4 |
| 7-3 | Baseline Status of Lower Columbia River Spring Chinook Salmon Populations | 7-8 |
| 7-4 | Baseline Status of Lower Columbia River Fall (Tule) Chinook Salmon Populations, per Management Unit Plans | 7-11 |
| 7-5 | Baseline Status of Columbia River Late-Fall Chinook Salmon Populations | 7-12 |
| 7-6 | Conservation Gaps for LCR Spring Chinook Salmon Populations: Difference between Baseline and Target Status | 7-18 |
| 7-7 | Conservation Gaps for LCR Fall and Late-Fall Chinook Salmon Populations: Difference between Baseline and Target Status | 7-18 |
| 8-1 | Life Cycle of Columbia River Chum Salmon | 8-2 |
| 8-2 | Baseline Status of Historical Columbia River Chum Salmon Populations | 8-5 |
| 8-3 | Conservation Gaps for Columbia River Chum Salmon Populations: Difference between Baseline and Target Status | 8-10 |
| 9-1 | Life Cycle of LCR Summer Steelhead | 9-3 |
| 9-2 | Life Cycle of Winter Steelhead | 9-4 |
| 9-3 | Baseline Status of LCR Summer Steelhead Populations | 9-8 |
| 9-4 | Baseline Status of LCR Winter Steelhead Populations | 9-9 |
| 9-5 | Conservation Gaps for LCR Winter Steelhead Populations: Difference between Baseline and Target Status | 9-14 |
| 9-6 | Conservation Gaps for LCR Summer Steelhead Populations: Difference between Baseline and Target Status | 9-14 |
| 10-1 | The Adaptive Management Cycle | 10-2 |
| 10-2 | NMFS Listing Status Decision Framework | 10-4 |
| 11-1 | Lower Columbia Recovery Plan Implementation Organizational Structure | 11-6 |
| 11-2 | Oregon's Organizational Implementation Structure | 11-11 |
| 11-3 | Institutional Structure for Implementing Salmon Recovery in Washington Lower Columbia River Subbasins | 11-14 |

# Acronyms and Abbreviations

| | |
|---|---|
| AMIP | Adaptive Management Implementation Plan |
| AMS | Anadromous Salmonid Monitoring Strategy |
| ASMS | Anadromous Salmonid Monitoring Strategy |
| BACI | Before and After Control Impact |
| BiOp | Biological Opinion |
| BPA | Bonneville Power Administration |
| C&S | ceremonial and subsistence |
| C3 | Climate Change Collaboration |
| CATAS | Conservation Assessment Tool for Anadromous Salmonids |
| CBFWA | Columbia Basin Fish and Wildlife Authority |
| CFR | Code of Federal Regulations |
| CREP | Conservation Reserve Enhancement Program |
| CRT | critical risk threshold |
| DEIS | Draft Environmental Impact Statement |
| DPS | distinct population segment |
| EDT | Ecosystem Diagnosis and Treatment |
| EIS | environmental impact statement |
| EPA | U.S. Environmental Protection Agency |
| ERME | *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program* |
| ESA | Endangered Species Act |
| ESU | evolutionarily significant unit |
| FCRPS | Federal Columbia River Power System |
| FERC | Federal Energy Regulatory Commission |

| | |
|---|---|
| FR | Federal Register |
| GHG | greenhouse gas |
| GIS | geographical information system |
| GRTS | generalized random tessellation stratified |
| HGMP | Hatchery and Genetics Management Plan |
| HSRG | Hatchery Scientific Review Group |
| IMW | intensively monitored watershed |
| IP | intrinsic potential |
| IPCC | Intergovernmental Panel on Climate Change |
| ISAB | Independent Scientific Advisory Board |
| ISEMP | Integrated Status and Effectiveness Monitoring Program |
| ISTM | Integrated Status and Trend Monitoring |
| IWA | Integrated Watershed Assessment |
| kcfs | thousand cubic feet per second |
| LCFRB | Lower Columbia Fish Recovery Board |
| LCR | Lower Columbia River |
| MAT | minimum abundance threshold |
| MOA | Memorandum of Agreement |
| MPG | major population group |
| NEPA | National Environmental Protection Act |
| NFCP | Native Fish Conservation Policy |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NPCC | Northwest Power and Conservation Council |
| NWFSC | Northwest Fisheries Science Center |
| ODFW | Oregon Department of Fish and Wildlife |

| | |
|---|---|
| OWEB | Oregon Watershed Enhancement Board |
| PAHs | polycyclic aromatic hydrocarbons |
| PCBs | polychlorinated biphenyls |
| PCE | primary constituent element |
| PCSRF | Pacific Coastal Salmon Recovery Funds |
| pHOS | proportion of hatchery-origin spawners |
| PNAMP | Pacific Northwest Aquatic Monitoring Partnership |
| PNI | proportion of natural influence |
| PUD | public utility district |
| PVA | Population Viability Analysis |
| QET | quasi-extinction threshold |
| RCW | Revised Code of Washington |
| RIST | Recovery Implementation Science Team |
| RKM | river kilometer |
| RM | river mile |
| RME | research, monitoring, and evaluation |
| RPA | Reasonable and Prudent Alternative |
| RSW | removable spillway weirs |
| SRFB | Salmon Recovery Funding Board |
| SRS | sediment retention structure |
| TRT | Technical Recovery Team |
| USC | United States Code |
| USDA | U.S. Department of Agriculture |
| USDI | U.S. Department of the Interior |
| USFWS | U.S. Fish and Wildlife Service |
| VSP | viable salmonid populations |

WAGIT Washington Gorge Implementation Team

WDFW Washington Department of Fish and Wildlife

WLC TRT Willamette-Lower Columbia Technical Recovery Team

WRIA Water Resource Inventory Area

# Glossary

**abundance:** In the context of salmon recovery, unless otherwise qualified, abundance refers to the number of adult fish returning to spawn, measured over a time series.

**adaptive management:** Adaptive management in salmon recovery planning is a method of decision making in the face of uncertainty. A plan for monitoring, evaluation, and feedback is incorporated into an overall implementation plan so that the results of actions can become feedback on design and implementation of future actions.

**anadromous fish:** Species that are hatched in freshwater, migrate to and mature in salt water, and return to freshwater to spawn.

**baseline monitoring:** In the context of recovery planning, baseline monitoring is done before implementation, in order to establish historical and/or current conditions against which progress (or lack of progress) can be measured.

**biogeographical region:** an area defined in terms of physical and habitat features, including topography and ecological variations, where groups of organisms (in this case, salmonids) have evolved in common.

**broad sense recovery goals:** Goals defined in the recovery planning process, generally by local recovery planning groups, that go beyond the requirements for delisting, to address, for example, other legislative mandates or social, economic, and ecological values.

**compliance monitoring:** Monitoring to determine whether a specific performance standard, environmental standard, regulation, or law is met.

**conservation gap:** The difference between a population's baseline status and its target status.

**contributing population:** A population for which some restoration will be needed to achieve the stratum-wide average viability recommended by the Washington-Lower Columbia Technical Recovery Team (i.e., 2.25 or higher).

**delisting criteria:** Criteria incorporated into ESA recovery plans that define both biological viability (biological criteria) and alleviation of the causes for decline (threats criteria based on the five listing factors in ESA section 4[a][1]), and that, when met, would result in a determination that a species is no longer threatened or endangered and can be proposed for removal from the federal list of threatened and endangered species. These criteria are a NMFS determination and may include both technical and policy considerations.

**distinct population segment (DPS):** A listable entity under the ESA that meets tests of discreteness and significance according to USFWS and NMFS policy. A population is considered distinct (and hence a "species" for purposes of conservation under the ESA)

if it is discrete from and significant to the remainder of its species based on factors such as physical, behavioral, or genetic characteristics, it occupies an unusual or unique ecological setting, or its loss would represent a significant gap in the species' range.

**diversity:** All the genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variations could include anadromy vs. lifelong residence in freshwater, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, physiology, molecular genetic characteristics, etc.

**effectiveness monitoring:** Monitoring set up to test cause-and-effect hypotheses about recovery actions: Did the management actions achieve their direct effect or goal? For example, did fencing a riparian area to exclude livestock result in recovery of riparian vegetation?

**endangered species:** A species in danger of extinction throughout all or a significant portion of its range.

**ESA recovery plan:** A plan to recover a species listed as threatened or endangered under the U.S. Endangered Species Act (ESA). The ESA requires that recovery plans, to the extent practicable, incorporate (1) objective, measurable criteria that, when met, would result in a determination that the species is no longer threatened or endangered; (2) site-specific management actions that may be necessary to achieve the plan's goals; and (3) estimates of the time required and costs to implement recovery actions.

**evolutionarily significant unit (ESU):** A group of Pacific salmon or steelhead trout that is (1) substantially reproductively isolated from other conspecific units and (2) represents an important component of the evolutionary legacy of the species.

**extinct:** No longer in existence. No individuals of this species can be found.

**extirpated:** Locally extinct. Other populations of this species exist elsewhere. Functionally extirpated populations are those of which there are so few remaining numbers that there are not enough fish or habitat in suitable condition to support a fully functional population.

**factors for decline:** Five general categories of causes for decline of a species, listed in the Endangered Species Act section 4(a)(1)(b): (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or human-made factors affecting its continued existence.

**functionally extirpated:** Describes a species that has been extirpated from an area; although a few individuals may occasionally be found, there are not enough fish or habitat in suitable condition to support a fully functional population.

**hyporheic zone:** Area of saturated gravel and other sediment beneath and beside streams and rivers where groundwater and surface water mix.

**implementation monitoring:** Monitoring to determine whether an activity was performed and/or completed as planned.

**independent population:** Any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations.

**indicator:** A variable used to forecast the value or change in the value of another variable.

**interim regional recovery plan:** A recovery plan that is intended to lead to an ESA recovery plan but that is not yet complete. These plans might address only a portion of an ESU or lack other key components of an ESA recovery plan.

**intrinsic potential:** The estimated relative suitability of a habitat for spawning and rearing of anadromous salmonid species under historical conditions inferred from stream characteristics including channel size, gradient, and valley width.

**intrinsic productivity:** The expected ratio of natural-origin offspring to parent spawners at levels of abundance below carrying capacity.

**kelts:** Steelhead that are returning to the ocean after spawning and have the potential to spawn again in subsequent years (unlike most salmon, steelhead do not necessarily die shortly after spawning).

**large woody debris (LWD):** A general term for wood naturally occurring or artificially placed in streams, including branches, stumps, logs, and logjams. Streams with adequate LWD tend to have greater habitat diversity, a natural meandering shape, and greater resistance to flooding.

**legacy effects:** Impacts from past activities that continue to affect a stream or watershed in the present day.

**limiting factor:** Physical, biological, or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) experienced by the fish that result in reductions in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Key limiting factors are those with the greatest impacts on a population's ability to reach a desired status.

**locally developed recovery plan:** A plan developed by state, tribal, regional, or local planning entities to address recovery of a species. These plans are being developed by a number of entities throughout the region to address ESA as well as state, tribal, and local mandates and recovery needs.

**maintained status:** Population status in which the population does not meet the criteria for a viable population but does support ecological functions and preserve options for ESU/DPS recovery.

**management unit:** A geographic area defined for recovery planning purposes on the basis of state, tribal or local jurisdictional boundaries that encompass all or a portion of

the range of a listed species, ESU, or DPS.

**metrics**: Something that quantifies a characteristic of a situation or process; for example, the number of natural-origin salmon returning to spawn to a specific location is a metric for population abundance.

**morphology:** The form and structure of an organism, with special emphasis on external features.

**natural-origin fish:** Fish that were spawned and reared in the wild, regardless of parental origin.

**parr:** The stage in anadromous salmonid development between absorption of the yolk sac and transformation to smolt before migration seaward.

**persistence probability:** The complement of a population's extinction risk (i.e., persistence probability = 1 – extinction risk).

**phenotype:** Any observable characteristic of an organism, such as its external appearance, development, biochemical or physiological properties, or behavior.

**piscivorous: (Adj.)** Describes fish that eat other fish.

**primary population:** A population that is targeted for restoration to high or very high persistence probability.

**productivity:** The average number of surviving offspring per parent. Productivity is used as an indicator of a population's ability to sustain itself or its ability to rebound from low numbers. The terms "population growth rate" and "population productivity" are interchangeable when referring to measures of population production over an entire life cycle. Can be expressed as the number of recruits (adults) per spawner or the number of smolts per spawner.

**recovery domain:** An administrative unit for recovery planning defined by NMFS based on ESU boundaries, ecosystem boundaries, and existing local planning processes. Recovery domains may contain one or more listed ESUs.

**recovery goals:** Goals incorporated into a locally developed recovery plan, which may include delisting (i.e. no longer considered endangered or threatened), reclassification (e.g., from endangered to threatened), and/or other goals. Broad sense goals are a subset of recovery goals (see glossary entry above).

**recovery scenarios:** Scenarios that describe a target status for each population within an ESU, generally consistent with TRT recommendations for ESU viability.

**recovery strategy:** Statements that identify the assumptions and logic – the rationale – for the species' recovery program.

**redd:** A nest constructed by female salmonids in streambed gravels where eggs are fertilized and deposited.

**riparian area:** Area with distinctive soils and vegetation between a stream or other body of water and the adjacent upland.

**salmonid:** Fish of the family *Salmonidae*, including salmon, trout, chars, grayling, and whitefish. In general usage, the term usually refers to salmon, trout, and chars.

**smolt:** A juvenile salmonid that is undergoing physiological and behavioral changes to adapt from freshwater to saltwater as it migrates toward the ocean.

**spatial structure:** Characteristics of a fish population's geographic distribution. Current spatial structure depends upon the presence of fish, not merely the potential for fish to occupy an area.

**stabilizing population:** A population that is targeted for maintenance at its baseline persistence probability, which is likely to be low or very low.

**stakeholders:** Agencies, groups, or private citizens with an interest in recovery planning, or those who will be affected by recovery planning and actions.

**stratum:** A group of salmonid populations that are geographically and genetically cohesive. The stratum is a level of organization between demographically independent populations and the ESU or DPS.

**Technical Recovery Team (TRT):** Teams convened by NMFS to develop technical products related to recovery planning. Planning forums unique to specific states, tribes, or regions may use TRT and other technical products to identify recovery actions.

**threatened species:** A species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

**threat reduction scenario**: A specific combination of reductions in threats from various sectors that would lead to a population achieving its target status.

**threats:** Human activities or natural events (e.g., road building, floodplain development, fish harvest, hatchery influences, volcanoes) that cause or contribute to limiting factors. Threats may exist in the present or be likely to occur in the future.

**viability criteria:** Criteria defined by NMFS-appointed Technical Recovery Teams to describe a viable salmonid population, based on the biological parameters of abundance, productivity, spatial structure, and diversity. These criteria are used as technical input into the recovery planning process and provide a technical foundation for development of biological delisting criteria.

**viability curve:** A curve describing combinations of abundance and productivity that yield a particular risk of extinction at a given level of variation over a specified time frame.

**viable salmonid population (VSP):** An independent population of any Pacific salmonid (genus *Oncorhynchus*) that has a negligible risk of extinction due to threats from demographic variation (random or directional), local

environmental variation, and genetic diversity changes (random or directional ) over a 100-year time frame.

**VSP parameters:** Abundance, productivity, spatial structure, and diversity. These describe characteristics of salmonid populations that are useful in evaluating population viability. See NOAA Technical Memorandum NMFS-NWFSC-42, *Viable salmonid populations and the recovery of evolutionarily significant units* (McElhany et al. 2000).

# Executive Summary

## About This Recovery Plan

This is a plan for the recovery of Lower Columbia River Chinook salmon (*Oncorhynchus tshawytscha*), Lower Columbia River steelhead (*O. mykiss),* Lower Columbia River coho salmon (*O. kisutch*), and Columbia River chum salmon (*O. keta*), all of which spawn and rear in the lower Columbia River or its tributaries in Oregon and Washington. These salmon and steelhead were listed as threatened under the Endangered Species Act of 1973 (ESA) between 1998 and 2005. Each is considered an evolutionarily significant unit (ESU) or, for steelhead, a distinct population segment (DPS). An ESU or DPS is a group of Pacific salmon or steelhead that is discrete from other groups of the same species and that represents an important component of the evolutionary legacy of the species.[1] Under the Endangered Species Act, each ESU or DPS is treated as a species. For convenience this recovery plan frequently uses the term "ESU" to refer to both the salmon ESUs and the steelhead DPS.

The core of the plan is a set of goals and actions for each ESU that, if implemented, would reverse the ESU's decline and lead to recovery of the ESU. Biological recovery for an ESU means that it is naturally self-sustaining and no longer requires the protection of the ESA: enough fish spawn in the wild and return year after year that the ESU is likely to persist in the long run. A recovered ESU is resilient enough that it can survive typical variations in ocean conditions and productivity and has a high likelihood of withstanding catastrophic changes in the environment, such as floods, landslides, and earthquakes.

The ESA requires the National Marine Fisheries Service (NMFS) to develop recovery plans for all listed salmon and steelhead species. NMFS is a branch of the National Oceanic and Atmospheric Administration and is sometimes referred to as NOAA Fisheries. As the federal agency charged with stewardship of the nation's marine resources, NMFS has the responsibility for listing and delisting salmon and steelhead species under the ESA.

Although NMFS is directly responsible for ESA recovery planning for salmon and steelhead, the agency believes that ESA recovery plans for salmon and steelhead should be based on the many state, regional, tribal, local, and private conservation efforts already under way throughout the region, and that local support of recovery plans is essential to success. Accordingly, NMFS based this recovery plan on the information, analyses, and strategies in three locally developed recovery plans, which are referred to as management unit plans.

Each ESU is made up of multiple independent populations, and each management unit plan covers populations in a different portion of the ESU's range:

[1] A DPS is defined based on discreteness in behavioral, physiological, and morphological characteristics, whereas the definition of an ESU emphasizes genetic and reproductive isolation. (For a fuller explanation see, Section 1.4.4 of the recovery plan.)

- *The Oregon Lower Columbia Conservation and Recovery Plan for Salmon and Steelhead* covers the Lower Columbia River salmon and steelhead populations that are within Oregon, including the Willamette River up to Willamette Falls. The Oregon Department of Fish and Wildlife (ODFW) developed this plan in collaboration with NMFS and numerous stakeholders, including governments, agencies, tribes, industry and environmental representatives, and the public (Oregon Department of Fish and Wildlife 2010).

- *ESA Salmon Recovery Plan for the White Salmon River Subbasin* covers Lower Columbia River salmon and steelhead populations in the White Salmon River basin in Washington. NMFS developed this plan in cooperation with stakeholders such as the Yakama Nation, Klickitat County, and Washington Department of Fish and Wildlife (National Marine Fisheries Service 2013).

- *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* covers Lower Columbia River salmon and steelhead populations in Southwest Washington, within the planning area of the Lower Columbia Fish Recovery Board (LCFRB). The LCFRB developed this plan using a collaborative process that involved multiple agencies (including NMFS), tribal and other governments, organizations, industry, and the public (Lower Columbia Fish Recovery Board 2010a).

Two other documents, both developed by NMFS, were key in development of this recovery plan: the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) and the *Recovery Plan Module: Mainstem Columbia River Hydropower Projects* (NMFS 2008a). These documents, which address regional-scale issues affecting Lower Columbia River salmon and steelhead, as well as other listed salmon ESUs and steelhead DPSs, provide a consistent set of assumptions and recovery actions that management unit recovery planners incorporated into their management unit plans.

Recovery plans are not regulatory documents. Their implementation is voluntary, except when they incorporate actions required as part of a regulatory process, such as ESA section 7, 10, and 4(d). For this recovery plan, NMFS will rely, to a great extent, on local citizens and organizations, as well as on other federal and state agencies, local jurisdictions, and tribal governments, to voluntarily implement the recovery actions. In some cases, the plan puts forward new recovery efforts that are not part of existing processes. In other cases, the plan recommends coordinating existing programs, both regulatory and non-regulatory, in ways that enhance benefits to Lower Columbia River salmon and steelhead and their ecosystems. Some actions that are integrated into this recovery plan originate in regulatory processes; examples include actions associated with the 2008 Bull Run Water Supply Habitat Conservation Plan (HCP), the 2008 Federal Columbia River Power System Biological Opinion and its 2010 Supplement, Federal Energy Regulatory Commission relicensing agreements (for tributary hydroelectric projects), and the regulation of fisheries that may affect the Lower Columbia River ESUs.

This recovery plan lays out an overall road map for recovery. After the plan is adopted, additional work will be needed in some cases to identify and prioritize[2] site-specific projects, determine costs and time frames, and identify responsible parties, based on strategies and actions in the recovery plan. To address these needs, each entity that developed a management unit plan (i.e., ODFW, NMFS, and LCFRB) also will prepare an "implementation schedule" that spells out the details of implementation for its specific geographical area. Implementation schedules will be updated every 3 to 6 years.

## Overall Goal

In general, the goal of this plan is for the Lower Columbia River coho salmon ESU, Lower Columbia River Chinook salmon ESU, Lower Columbia River steelhead DPS, and Columbia River chum salmon ESU to reach the point at which they no longer need the protection of the Endangered Species Act and can be delisted. The delisting decision is made by NMFS, using the best available science. NMFS' delisting criteria are presented later in this summary, after some basic technical information and the population-specific goals are explained.

## Technical Foundation

NMFS appointed teams of scientists with expertise in salmonid species to provide scientific support for recovery planners in the Pacific Northwest. These technical recovery teams (TRTs) worked from a common scientific foundation to ensure that recovery plans would be scientifically sound and based on consistent biological principles. All the TRTs based their work on biological principles established by NMFS for salmon recovery planning.

The Willamette-Lower Columbia Technical Recovery Team (WLC TRT) included biologists from NMFS, other federal agencies, states, tribes, academic institutions, and the private sector. The WLC TRT and a subsequent work group consisting of NMFS staff, ODFW staff, and a private consultant produced a set of technical reports that, taken together, present recommended biological criteria and methodologies for determining whether the four Lower Columbia River salmon and steelhead ESUs are viable. A viable ESU is naturally self-sustaining over the long term.

Consistent with principles established by NMFS, the WLC TRT described salmon and steelhead viability in terms of four interrelated parameters:

- **Abundance and productivity.** Abundance refers to the number of adult fish on the spawning grounds. Productivity is the population's growth rate, which indicates whether the population can sustain itself or rebound from low numbers. Productivity can be measured as spawner-to-spawner ratios (i.e., returns per spawner or recruits per spawner), annual population growth rate, or trends in abundance. Abundance and productivity are closely linked, and a population needs both: abundance to maintain genetic health and respond to normal

[2] Some prioritization work already has been done, in that the management unit plans identify high-priority reaches for tributary habitat protection and restoration actions. In addition, the Oregon and White Salmon management unit plans offer some guidance on how actions might be prioritized.

environmental variation, and productivity to bounce back if population numbers drop for some reason.

- **Spatial structure.** Spatial structure refers to both the geographic distribution of individuals in the population and the processes or conditions that generate that distribution. Factors affecting spatial structure include the amount of habitat available, how connected the habitat is, and how much neighboring populations mix with each other. Spatial structure is important because a species that is not geographically spread out is at risk of extinction from a single catastrophic event, such as a landslide.

- **Diversity**. Diversity refers to the variety of life history, behavioral, and physiological traits within and among populations. Some traits are determined completely by genetics, while others, such as appearance, behavior, and life history, vary as a result of a combination of genetic and environmental factors. Diversity is important because it gives populations an edge in surviving (and eventually adapting to) environmental change.

To understand the WLC TRT's biological criteria, it helps to know something about the biological structure of salmon and steelhead species. The Lower Columbia River Chinook salmon, Lower Columbia River coho salmon, Lower Columbia River steelhead, and Columbia River chum salmon ESUs each consist of multiple independent populations that spawn in different watersheds throughout the ESU's range. Additionally, within an ESU, independent populations can be organized into larger groups, known as strata. Stratum designation is based on the combination of ecological zone and life history strategy (indicated by the time of year when adults return to fresh water to spawn). In the lower Columbia region there are three ecological zones—Coast, Cascade, and Gorge. Two ESUs—Chinook and steelhead—display more than one life history strategy. Thus, the strata in this recovery plan include Coast, Cascade, and Gorge coho, Coast fall Chinook, Cascade fall Chinook, Gorge fall Chinook, Cascade spring Chinook, Gorge spring Chinook, etc.

The WLC TRT developed biological criteria and methodologies at three different levels: ESU, stratum, and population. The following are the TRT's key points in defining a viable ESU:

- Every stratum that historically existed should have a high probability of persistence.

- Within each stratum, there should be at least two populations that have at least a 95 percent probability of persisting over a 100-year time frame.

- Within each stratum, the average viability of the populations should be 2.25 or higher, using the WLC TRT's scoring system. Functionally, this is equivalent to about half of the populations in the stratum being viable; a viable population is one whose persistence probability is high or very high.

- Populations targeted for viability should include those within the ESU that historically were the most productive ("core" populations) and that best represent the historical genetic diversity of the ESU ("genetic legacy" populations). In

addition, viable populations should be geographically dispersed in a way that protects against the effects of catastrophic events.

- Viable populations should meet specific criteria for abundance, productivity, spatial structure, and diversity.

There are various ways to refer to extinction risk: as viability, persistence probability, extinction risk, or—at the population level—population status. This recovery plan frequently uses the terms "persistence probability" and "population status." Only populations with a persistence probability of 95 percent or higher over a 100-year time frame are considered viable. These populations have a population status of high or very high.

**Table ES-1**
*Population-level Probability* of Persistence, Extinction Risk, and Status*

| Probability of Persistence | Probability of Extinction | Extinction Risk | Population Status |
|---|---|---|---|
| 0 – 40% | 60 – 100% | Extinct or at very high risk of extinction (VH) | Very low (VL) |
| 40 – 75% | 25 – 60% | Relatively high risk of extinction (H) | Low (L) |
| 75 – 95% | 5 – 25% | Moderate risk of extinction (M) | Medium (M) |
| 95 – 99% | 1 – 5% | Low/negligible risk of extinction (L) | High (H) |
| > 99% | < 1% | Very low risk of extinction (VL) | Very high (VH) |

[+] Probability over a 100-year time frame.
Shading indicates levels at which a population is considered viable.

## Population-specific Goals: The Recovery Scenario

The WLC TRT defined viability at the ESU, stratum, and population levels, but it did not specify the target status for each population because (1) there are many different combinations of target statuses that would meet the TRT's viability criteria, and (2) the "best" combination is a function of the biological and ecological conditions on the ground and local community values and interests. Oregon, Washington, and White Salmon management unit planners collaborated to reach agreement on which populations to target for which levels of viability. In making these decisions, management unit planners considered the WLC TRT's viability criteria and the following questions:

- Which populations historically were the most productive?
- Which populations represent important historical genetic diversity?
- Are the populations targeted for viability dispersed in a way that minimizes risk from catastrophic events?
- Which populations can be expected to make significant progress toward recovery because of existing programs, the absence of apparent impediments to recovery, and other management considerations?

- Are there populations that are unlikely to make significant progress toward recovery because of other societal goals, such as maintaining harvest or development opportunities?

The resulting target statuses for each ESU are collectively referred to as the recovery scenario and served as the basis from which to calculate numerical abundance and productivity goals for each population. (Table 3-1 of the recovery plan shows the recovery scenario for each ESU.)

Under the recovery scenario not all populations are targeted for a high degree of improvement, but all of them will need recovery actions—even so-called "stabilizing" populations. These are populations that are expected to remain at or near their current status (usually low or very low) because the feasibility of restoration is low and the uncertainty of success is high. "Primary" populations, on the other hand, are targeted for viability, meaning high or very high persistence probability. "Contributing" populations fall in the middle; they are targeted for some improvement in status so that the stratum-wide average viability is 2.25 or higher.

The recovery scenarios in the management unit plans are largely consistent with the WLC TRT's recommendations at the stratum and ESU level. Exceptions are the Gorge fall Chinook, Gorge spring Chinook, and Gorge chum strata, where the recovery scenarios target only one population to achieve a high probability of persistence, instead of two. As a way of mitigating for this increased risk in the Gorge strata, the recovery scenarios exceed the WLC TRT criteria in the Cascade fall Chinook, Cascade spring Chinook, and Cascade chum strata (i.e., more populations are targeted for viability than are needed to meet the 2.25 average). In addition, management unit recovery planners raised questions about the historical role of the Gorge fall Chinook, spring Chinook, and chum populations: were the populations highly persistent historically, did they function as independent populations within their stratum in the same way that the Coast and Cascade populations did, and should the Gorge stratum be considered a separate stratum from the Cascade stratum? Oregon recovery planners suggested that the Gorge strata's historical status and population structure be reevaluated and that recovery goals be revised if modifications are made; NMFS agrees that the historical role of the Gorge populations and strata merits further examination.

## NMFS Delisting Criteria

As described above, the overall goal of this recovery plan is for the four ESUs to reach the point at which they no longer need the protection of the ESA and can be delisted. In order to be delisted, the species must no longer be in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the factors that caused the species to be listed in the first place. In accordance with the ESA, this recovery plan incorporates objective, measurable criteria for determining whether an ESU can be delisted.[3] These criteria are of two types: biological viability criteria and threats criteria.

[3] The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the

### Biological Viability Criteria

NMFS has concluded that the WLC TRT's viability criteria, the recovery scenarios, and the population-level abundance and productivity goals in the management unit plans adequately describe the characteristics of an ESU that no longer needs the protections of the ESA. NMFS endorses the recovery scenarios and population-level goals in the management unit plans as one of multiple possible scenarios consistent with delisting. Therefore, NMFS has developed the following biological viability criteria:

- All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition.

- High probability of stratum persistence is defined as:

    A. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

    B. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 of the recovery plan for a brief discussion of the TRT's scoring system.)

    C. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

- Probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

### Threats Criteria

In addition, for a species to be delisted, the threats that brought it to its threatened or endangered condition must be ameliorated such that they do not keep the ESU from achieving the desired biological status. The ESA identifies five categories of threats (any one or a combination of which may be the basis for the initial listing):

A. Present or threatened destruction, modification, or curtailment of the species' habitat or range
B. Overutilization for commercial, recreational, scientific, or educational purposes
C. Disease or predation

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ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12).

D. Inadequacy of existing regulatory mechanisms
E. Other natural or human-made factors affecting the species' continued existence

The threats criteria in this recovery plan define the conditions under which the threats can be considered to be addressed or mitigated. Threats criteria for measuring recovery of Lower Columbia River salmon and steelhead ESUs are detailed in Section 3.2.2 of the recovery plan. In general, the threats criteria for the Lower Columbia River ESUs are considered met once the recovery plan actions have been substantially implemented, population-specific threat reduction targets have been met (or threat impacts are otherwise consistent with the desired status of the ESU and its constituent populations), threats have been ameliorated such that the desired status will be maintained, and regulatory mechanisms are being implemented in a way that supports attainment and maintenance of the desired status.

## Site-specific Recovery Actions and Cost Estimates

Site-specific recovery actions are discussed in detail in the management unit plans. The Federal Columbia River Power System (FCRPS) Biological Opinion and related recovery plan hydropower module describe site-specific actions related to passage at Bonneville Dam, predation, and flow that affects conditions in the lower Columbia River, estuary, and, potentially, the plume. Site-specific actions for the Columbia River estuary and plume are presented in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead*.

The total estimated cost of recovery actions for the four threatened species in the lower Columbia River over the next 25 years is approximately $2.1 billion, of which about $614 million is expected to be needed in the first 5 years (see Table ES-2). These estimates include expenditures by local, tribal, state, and federal governments, private business, and individuals in implementing capital projects and non-capital work, as well as administrative costs for supervision and coordination. The total estimated cost includes $592 million ($164 in the first 5 years) for actions in the Columbia River estuary that are basinwide in scope and are expected to benefit all 13 listed ESUs and DPSs in the Columbia Basin.

The estimates are based on the best available information at the time the management unit plans were completed and are expected to change as implementation schedules are developed and actions are more clearly scoped and planned. Given that the costs for many actions could not be estimated at the time the management unit plans were completed, it is likely that actual costs will be substantially higher than the estimated costs in Table ES-2.

**Table ES-2**
*Summary of Cost Estimates*

| Management Unit | 5-Year Cost Estimate (millions) | 25-Year Cost Estimate (millions) |
|---|---|---|
| Washington | $245 | $738 |
| Oregon | $189 | $758 |
| White Salmon | $16 | $16 |
| Columbia River Estuary | $164 | $592 |
| TOTAL | $614 | $2,104 |

The remaining sections of this summary focus mostly on the results of the recovery analysis for each ESU. After briefly explaining the overall approach used to complete the ESU recovery analyses, the summary describes general categories of limiting factors that affect multiple ESUs throughout the Lower Columbia region and strategies for addressing those limiting factors at the regional or programmatic level. This is followed by an individual section for each ESU that highlights that ESU's baseline and target status, the factors that are limiting its viability, and the strategy for reducing limiting factors and threats and achieving recovery. The summary concludes with thoughts on the role of research, monitoring, evaluation, and adaptive management and how recovery actions will be coordinated and implemented. Key documents referred to in this summary are listed at the end.

## Overall Approach to ESU Recovery Analyses

This recovery plan addresses the needs of each ESU individually, based on analyses in the three management unit plans. Although each recovery planning team used a slightly different process in developing its management unit plan, all of the teams worked from the same TRT recommendations and a consistent set of assumptions about what elements should be included in their plans. Thus, the different recovery planning teams followed the same overall approach in their recovery analyses. In general, the management unit recovery planners did the following:

1. Evaluated the baseline status of their respective populations using techniques based on those recommended by the WLC TRT.[4]

2. Identified limiting factors for each Lower Columbia River salmon and steelhead population.

3. For each population, quantified the estimated baseline impacts of six categories of threats—tributary habitat loss and degradation, estuary habitat loss and degradation, hydropower, harvest, hatcheries, and ecological interactions.

[4] Both Oregon and Washington management unit planners established a baseline period from which to assess population status, limiting factors, and threat impacts. For more discussion, see Sections 5.1 and 5.5.

4. Established a target status for each population, taking into consideration (1) each population's potential for improvement, in view of available habitat and historical production, (2) the degree of improvement needed in each stratum to meet WLC TRT guidelines for a viable ESU, and (3) for some ESUs, the desire to accommodate objectives such as maintaining opportunities to harvest hatchery-origin fish.

5. Calculated the improvements in abundance and productivity and, in some cases, spatial structure and diversity, that each population would need to achieve its target status (i.e., to close the "conservation gap," which is the difference between the baseline and target status for each population).

6. Identified a "threat reduction scenario" for each population, meaning a specific combination of reductions in threats that would lead to the population achieving its target status.

7. Identified and scaled recovery strategies and actions to reduce threats by the targeted amount in each category. Management unit planners identified recovery strategies and actions through workshops and meetings with stakeholders, including representatives of implementing and affected entities.

8. Considered the probable effects of actions, established benchmarks for implementation, and identified critical uncertainties and research, monitoring, and evaluation needs for each species.

9. Developed implementation frameworks that address organizational structures for implementation of the actions, prioritization methods, tracking systems, coordination needs and approaches, and stakeholder involvement.

Given the complexity of the salmonid life cycle and the fact that complete data were not available for every population, some elements of the recovery analyses are subject to significant levels of uncertainty and should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and the management unit scientists that, based on the best available information at this time, the results of the management unit plan analyses provide reasonable estimates of the relative magnitude of different threats to each population and the improvements that need to be addressed through recovery actions. Thus, NMFS considers the management plan analyses an adequate basis for designing initial recovery actions. As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework that involves action implementation, monitoring of results, and adjustment of actions as needed.

The management unit plans' recovery analyses indicate that no single factor, threat, or threat category accounts for the declines in the species addressed in this recovery plan. Instead, the status of Lower Columbia River salmon and steelhead and Columbia River chum is the result of the cumulative impact of multiple limiting factors and threats. Thus, recovery will be accomplished through improvements in every general threat category. Even small increments of improvement will play an important role. When the

need for improvement for most ESUs is so large, the contribution of no population or threat reduction can be discounted.

## Regional Limiting Factors and Strategies

The reasons for a species' decline are generally described in terms of limiting factors and threats. Limiting factors are biological, physical, or chemical conditions and associated ecological processes and interactions that limit a species' viability. Threats are human activities or natural events, such as floodplain development or drought, that cause or contribute to limiting factors. Although the management unit plans analyze limiting factors and threats for each population, it also can be helpful to view limiting factors and threats from a regional, multi-species perspective—to discern large-scale patterns in ecological conditions that are affecting all or most of the listed ESUs. This aids in identifying regional approaches to recovery that can provide high biological benefit while making effective use of limited resources. The sections below describe such regional strategies, which are general approaches that either benefit multiple ESUs or can be tailored to meet the specific needs of each species. However, implementation of the regional strategies alone will not necessarily lead to recovery. The regional strategies are intended to supplement ESU-specific strategies that provide greater specificity and address specific needs at the species, stratum, and population levels.

### Tributary Habitat

Tributary habitat degradation from past and/or current land and water use is a limiting factor for all Lower Columbia River salmon and steelhead populations. Widespread development and other land use activities have disrupted watershed processes, reduced water quality, and diminished habitat quantity, quality, and complexity in most lower Columbia River subbasins. Past and/or current land use or water management activities have adversely affected stream and side channel structure, riparian conditions, floodplain function, sediment conditions, and water quality and quantity, as well as the watershed processes that create and maintain properly functioning conditions for salmon and steelhead.

The regional tributary habitat strategy is directed toward habitat protection and restoration to achieve adequate quantities of high-quality, well-functioning salmon and steelhead habitat. This will be accomplished through a combination of (1) site-specific projects that will protect habitat or provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Although many habitat-related actions already have been undertaken, current activities do not reflect the scale of habitat improvements needed. Recovery of the listed species will require concerted efforts to protect remaining areas of favorable habitat and restore habitat quality in significant historical production areas. There is an immediate need to complete prioritization frameworks and get additional targeted, site-specific protection and restoration actions, as well as programmatic approaches, on the ground as soon as possible, especially because the benefits of some habitat actions will take years to accrue. Table ES-3 lists subbasins that will play a key role in recovery because they are targeted to support multiple primary populations, from different ESUs.

**Table ES-3**
*Subbasins Targeted to Support Three or More Primary Populations*

| Ecozone | Subbasin | Primary Populations |
|---|---|---|
| Coast | Elochoman | Fall Chinook, chum, coho |
| | Clatskanie | Fall Chinook, chum, coho |
| | Scappoose | Fall Chinook, chum, coho |
| Cascade | Coweeman | Fall Chinook, winter steelhead, coho |
| | SF Toutle | Fall Chinook, winter steelhead, coho |
| | NF Toutle | Fall Chinook, winter steelhead, coho |
| | Cispus | Spring Chinook, winter steelhead, coho |
| | Upper Cowlitz | Spring Chinook, winter steelhead, coho |
| | NF Lewis | Fall Chinook, late-fall Chinook, spring Chinook, chum |
| | EF Lewis | Fall Chinook, chum, winter steelhead, summer steelhead, coho |
| | Washougal | Fall Chinook, chum, summer steelhead |
| | Sandy | Late-fall Chinook, spring Chinook, chum, winter steelhead, coho |
| Gorge | Lower Gorge tribs | Chum, winter steelhead, coho |
| | Hood | Fall Chinook, spring Chinook, winter steelhead, summer steelhead, coho |

### Estuary Habitat

Habitat conditions in the Columbia River estuary and plume are important to the survival of all Columbia River basin salmon and steelhead during critical rearing, migration, and saltwater acclimation periods in their life cycle. Yet the amount and accessibility of in-channel, off-channel, and plume habitat have been reduced as a result of habitat conversion for agricultural, urban, and industrial uses, hydroregulation and flood control, channelization, and higher bankfull elevations, which have been facilitated by diking, dredging, and filling. Sediment conditions and toxic contaminants also have been identified as limiting factors in the estuary, as have high water temperatures in late summer and fall, changes in the food web, and predation.

Estuary habitat strategies focus on providing adequate off-channel and intertidal habitats, such as tidal swamp and marsh; restoring habitat complexity in areas modified by agricultural or rural residential use; decreasing exposure to toxic contaminants; and lowering water temperatures. This will be accomplished over the long term by restoring hydrologic, sediment, and riparian processes that structure habitat in the estuary. An aggressive, strategic approach needs to be developed for implementation of estuary actions.

### Hydropower

Bonneville Dam is the only mainstem hydropower facility within the geographic range of Lower Columbia River salmon and steelhead, but flow management at large storage reservoirs in the interior of the Columbia Basin affect habitat in the lower Columbia River mainstem and estuary, and potentially in the plume. In addition, significant

tributary hydropower dams are located on the Cowlitz and Lewis rivers in Washington and on the Willamette, Clackamas, and Sandy rivers in Oregon.[5] The impacts of hydropower facility construction and operation on Lower Columbia salmon and steelhead occur both locally (at, above, and immediately below dams) and downstream, in the Columbia River estuary and, potentially, the plume. Impacts include habitat inundation, impaired fish passage, higher water temperatures during the late summer and fall, and alterations in the timing and magnitude of flow that affect downstream habitat conditions and habitat-forming processes.

The regional hydropower strategy focuses on (1) improving passage survival at Bonneville Dam for Lower Columbia River populations that spawn above the dam, (2) addressing impacts in tributaries by implementing actions prescribed in Federal Energy Regulatory Commission agreements regarding operation of individual tributary dams, and (3) implementing mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. The regional hydropower strategy includes actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement that will aid adults and juveniles from the Gorge populations in passing Bonneville Dam. For chum salmon, the strategy involves ensuring adequate flows in the Bonneville Dam tailrace and downstream habitats during chum salmon migration, spawning, incubation, and emergence.

### Hatcheries

Hatchery practices such as broodstock collection and spawning protocols can cause genetic changes in hatchery fish. When hatchery-origin fish spawn with natural-origin fish, genetic changes can be transmitted to the naturally produced fish; the larger the proportion of hatchery-origin spawners, the larger the genetic effects to the natural population. These genetic effects can include domestication and loss of diversity within the population. For decades, high proportions of hatchery fish on the spawning grounds have been common among many Lower Columbia River salmon and steelhead populations, including the vast majority of Chinook and coho salmon populations. In addition, hatchery fish infected with pathogens or parasites have the potential to spread these organisms to natural-origin fish. Also, hatchery fish can sometimes prey directly on naturally produced juveniles, particularly chum salmon. Some scientists suspect that closely spaced releases of hatchery fish from Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the Columbia River estuary.

The overall goals of the hatchery recovery strategies for the Lower Columbia ESUs are to (1) reduce hatchery impacts on natural-origin populations as appropriate for each population, (2) ensure that some populations have no in-subbasin hatchery releases and are isolated from stray out-of-subbasin hatchery fish, (3) use hatchery stocks in the short term for reintroduction or supplementation programs to restore naturally spawning populations in some watersheds, and (4) ensure rigorous monitoring and evaluation to

[5] Powerdale Dam, on the Hood River, was removed in 2010; Condit Dam, on the White Salmon River, was breached in October 2011 and completely removed in September 2012.

better understand existing population status and the effects of hatchery strategies on natural populations.

### Harvest

Lower Columbia River Chinook salmon, steelhead, and coho salmon are caught in commercial, recreational, and tribal fisheries along the West Coast of the United States and Canada as well as in the mainstem Columbia River and its tributaries. These various fisheries focus on different stocks and populations, taking fish to meet commercial, recreational, and tribal harvest allocations. Harvest affects the viability of Lower Columbia River salmon and steelhead populations by causing mortality to naturally produced adult fish, influencing population traits, and reducing nutrients in freshwater ecosystems. Harvest mortality can be either direct or indirect. Direct harvest mortality is associated with fisheries that target specific stocks. Indirect mortality includes mortality of fish harvested incidentally to the targeted species or stock, fish that die after being captured by fishing gear but not landed, and fish that die after being caught and released. Harvest managers have implemented substantial reductions in harvest for Lower Columbia River species since they were listed under the ESA.

The management unit plans include the societal goal of maintaining harvest opportunities created by hatchery fish and have prioritized ESA recovery strategies that allow for continued harvest opportunities while working toward recovery; these strategies have been incorporated into the recovery plan. In addition, as part of their broad sense goals, the management unit plans envision eventual harvest of naturally produced salmon and steelhead from healthy, self-sustaining populations.[6]

Although each species' harvest management requirements are unique, in general the harvest strategy focuses on refining harvest management and reducing impacts to naturally produced fish where needed while maintaining harvest opportunities that target hatchery-produced fish. The recovery plan calls for the use of six general approaches as appropriate and feasible: abundance-based harvest management, weak-stock management, mark-selective harvest, filling information needs, ancillary and precautionary actions, and adaptive management.

Local recovery planners believe that for Lower Columbia River spring Chinook salmon, steelhead, and chum salmon, current harvest impacts are generally consistent with long-term recovery goals, at least in the near term. For these species the recovery plan recommends measures to ensure that harvest does not adversely affect future conservation and recovery. For Lower Columbia fall Chinook and coho salmon, efforts will focus on (1) refinements in harvest management (including abundance-based management) to reduce risk to naturally produced fish, and (2) continued review of overall harvest rates.

### Ecological Interactions

Anthropogenic changes to habitat in the lower Columbia River region have altered the

[6] Currently, targeted harvest on naturally produced North Fork Lewis late-fall Chinook salmon is occurring when returns are above the escapement goal. The baseline persistence probability of this population, which has remained largely uninfluenced by hatchery production and has not experienced the population bottlenecks common among tule fall Chinook salmon populations, is estimated to be high.

relationships between salmonids and other fish and wildlife species, leaving Lower Columbia River salmon and steelhead more vulnerable to predation by piscivorous fish, birds, and marine mammals (i.e., seals and sea lions) and subject to competition with introduced fish species and possibly hatchery-origin fish for limited food and habitat.

The regional ecological interactions strategy involves reducing predation on all Lower Columbia River salmon and steelhead populations by redistributing Caspian terns and cormorants, increasing the pikeminnow bounty program in the Columbia River mainstem, and reducing marine mammal predation at Bonneville Dam using non-lethal or lethal measures. Managing predation by sea lions at Bonneville Dam is expected to benefit Gorge-stratum populations of Lower Columbia River salmon and steelhead ESUs. To reduce the risk of adverse ecological interactions between hatchery-origin and naturally produced salmon and steelhead, the recovery plan proposes a combination of critical uncertainties research and near-term precautionary measures, such as restoring estuary habitat and managing hatchery releases to prevent large numbers of hatchery-origin fish from accumulating in the estuary.

### Climate Change

The warming rate for the Pacific Northwest over the next century is projected to be in the range of 0.1 to 0.6 °C per decade. Although total precipitation changes are predicted to be minor (+ 1 to 2 percent), increasing air temperature will alter snowpack, stream flow timing and volume, and water temperature in the Columbia Basin.

Changes in air temperatures, river temperatures, and river flows in the Pacific Northwest are expected to affect salmon and steelhead distribution, behavior, growth, and survival. The magnitude and timing of the changes are poorly understood, and specific effects are likely to vary among populations. However, likely effects on listed salmon and steelhead in fresh water include winter flooding of redds (i.e., salmon nests), earlier emergence of salmon fry, decreased parr-to-smolt survival, reductions in the quantity and quality of juvenile rearing habitat and possibly overwintering habitat, changes in the timing of smolt migration, and increased adult mortality or reduced spawning success as a result of higher water temperatures.

Possible effects on salmon and steelhead in estuaries include altered growth and disease susceptibility, reduced quality of rearing habitat, and changes in the distribution of salmonid prey and predators, including possible extension of the range of non-native species adapted to warm water.

Climate-related changes in the marine environment are expected to alter primary and secondary productivity, the structure of marine communities, and, in turn, the growth, productivity, survival, and migrations of salmonids, although the degree of impact on listed salmonids currently is poorly understood. A mismatch between earlier smolt migrations (because of earlier peak spring freshwater flows and shorter incubation periods) and altered coastal upwelling may reduce marine survival rates. Ocean warming also may change migration patterns, increasing distances to feeding areas.

In addition, rising atmospheric carbon dioxide concentrations drive changes in seawater chemistry, increasing the acidification of seawater and thus reducing the availability of carbonate for shell-forming invertebrates, including some that are prey items for

juvenile salmonids. Ocean acidification has the potential to reduce survival of many marine organisms, including salmon and steelhead. However, because there is currently a paucity of research directly related to the effects of ocean acidification on salmon and steelhead and their prey, potential effects are uncertain.

The regional climate change strategy has two parts: (1) implementation of greenhouse gas reduction strategies, such as through the West Coast Governors' Global Warming Initiative[7] and the Oregon Global Warming Commission's recommendations,[8] and (2) adaptation, to reduce the impacts of climate change on Pacific Northwest salmon and steelhead. Adaptation commonly involves the following:

- Conserving adequate habitat to support healthy fish populations and ecosystem functions in a changing climate
- Managing species and habitats to protect ecosystem functions in a changing climate
- Reducing stresses not caused by climate change
- Supporting adaptive management through integrated observation and monitoring and improved decision support tools

The management unit plans and estuary recovery plan module present specific actions that are responsive to these general strategies. The following documents also are relevant to adaptation:

- *Climate Change Impacts on Columbia River Basin Fish and Wildlife* (Independent Scientific Advisory Board 2007a)
- *Oregon Climate Change Adaptation Framework* (Oregon Department of Land Conservation and Development 2010)
- *Washington State Integrated Climate Change Response Strategy* (interim document) (Washington Department of Ecology 2011)
- *Draft National Fish, Wildlife, and Plants Climate Adaptation Strategy* (U.S. Fish and Wildlife Service et al. 2012)

### Human Population Growth

The Oregon and White Salmon management unit plans identify human population growth as a future threat to Lower Columbia River salmon and steelhead, based in part on work done by the Independent Scientific Advisory Board (ISAB), which provides independent scientific advice and recommendations related to the fish and wildlife management responsibilities of the Northwest Power and Conservation Council, Columbia River Basin Indian tribes, and NMFS. Expected population growth rates will vary throughout the lower Columbia region; however, the ISAB expects that human population growth in the Columbia Basin will increase the demand for water, land, and

[7] For the West Coast Governors' Global Warming Initiative, go to http://www.ef.org/westcoastclimate/.
[8] For the Oregon Global Warming Commission's recommendations, see Oregon Department of Energy (2009) or go to http://www.oregon.gov/ENERGY/GBLWRM/GWC/docs/09CommissionReport.pdf.

forests that are key to fish and wildlife populations. This demand for resources will increase threats to and extinction risks for fish and wildlife—including salmon and steelhead—through such mechanisms as loss, degradation, and fragmentation of habitat; increased stormwater runoff; and reduced groundwater recharge and thus base stream flows.

The recovery plan includes actions that will lessen the impacts of human population growth. The focus is on protecting existing high-quality habitat through acquisition and conservation; using land use planning to guide future development away from ecologically sensitive areas, such as wetlands and floodplains; implementing best management practices; protecting and restoring instream flows, runoff processes, and water quality; and educating landowners and others.

## Recovery Analysis: Lower Columbia River Coho Salmon

This recovery plan covers all naturally spawned coho salmon (*Oncorhynchus kisutch*) populations in the lower Columbia River and its tributaries, from the mouth of the Columbia upstream to the Hood River (in Oregon) and the White Salmon River (in Washington), including the Willamette River up to Willamette Falls. Twenty-three coho salmon hatchery programs also are part of the ESU.

Historically, the Lower Columbia River coho salmon ESU consisted of a total of 24 independent populations that spawned in almost every accessible stream system in the lower Columbia River basin. Coho salmon typically spawn in small to medium, low-to-moderate elevation streams from valley bottoms to stream headwaters. Coho salmon particularly favor small, rain-driven, lower elevation streams characterized by (1) relatively low flows during late summer and early fall, and (2) increased river flows and decreased water temperatures in winter.

### Baseline and Target Status: Coho Salmon

Today, 21 of the 24 Lower Columbia River coho salmon populations are considered to have a very low probability of persisting over the next 100 years, and none is considered viable. All three strata in the ESU fall significantly short of the WLC TRT criteria for viability.

**Table ES-4**
*Baseline and Target Status* of LCR Coho Salmon Populations*

| Stratum | Population | Contribution to Recovery | Baseline Status | Target Status |
|---|---|---|---|---|
| Coast | Youngs Bay (OR) | Stabilizing | VL | VL |
| | Grays/Chinook (WA) | Primary | VL | H |
| | Big Creek (OR) | Stabilizing | VL | VL |
| | Elochoman/Skamokawa (WA) | Primary | VL | H |
| | Clatskanie (OR) | Primary | L | VH |
| | Mill/Abernathy/Germany (WA) | Contributing | VL | M |
| | Scappoose (OR) | Primary | M | VH |
| Cascade | Lower Cowlitz (WA) | Primary | VL | H |
| | Upper Cowlitz (WA) | Primary | VL | H |
| | Cispus (WA) | Primary | VL | H |

| Stratum | Population | Contribution to Recovery | Baseline Status | Target Status |
|---|---|---|---|---|
| | Tilton (WA) | Stabilizing | VL | VL |
| | Toutle SF (WA) | Primary | VL | H |
| | Toutle NF (WA) | Primary | VL | H |
| | Coweeman (WA) | Primary | VL | H |
| | Kalama (WA) | Contributing | VL | L |
| | NF Lewis (WA) | Contributing | VL | L |
| | EF Lewis (WA) | Primary | VL | H |
| | Salmon Creek (WA) | Stabilizing | VL | VL |
| | Clackamas (OR) | Primary | M | VH |
| | Sandy (OR) | Primary | VL | H |
| | Washougal (WA) | Contributing | VL | M+ |
| Gorge | Lower Gorge (WA & OR) | Primary | VL | H |
| | Upper Gorge/White Salmon (WA) | Primary | VL | H |
| | Upper Gorge/Hood (OR) | Primary | VL | H* |

*Status is equivalent to persistence probability. VL = very low, L = low, M = moderate, H = high, VH = very high.

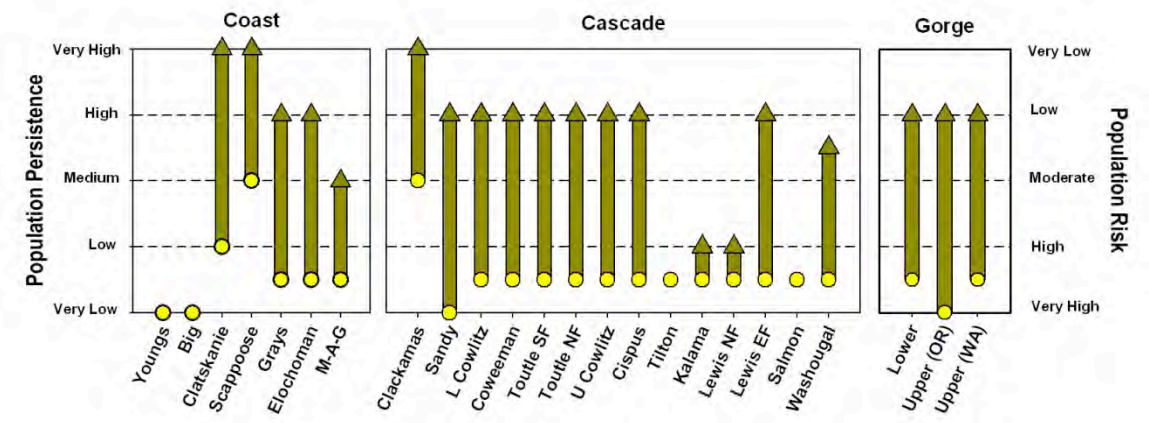


**Figure ES-1.** *Conservation Gaps for LCR Coho Salmon Populations (i.e., Difference between Baseline and Target Status)*

## Prevalent Limiting Factors: Coho Salmon

Lower Columbia River coho salmon's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Table ES-5 lists prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

In addition, tributary hydropower dams are a primary limiting factor for the Upper Cowlitz, North Fork Lewis, Cispus, Tilton, and Upper Gorge/White Salmon populations.

**Table ES-5**
*Prevalent Primary Limiting Factors for Coho Salmon during Baseline Period*

| Limiting Factor | Populations for Which This Is a Primary Limiting Factor |
|---|---|
| Degraded riparian conditions along tributaries | Almost all* |
| Impaired side channel and wetland conditions in tributaries | Almost all |
| Loss/degradation of floodplain habitat in tributaries | Almost all |
| Channel structure and form issues[9] in tributaries and the Columbia River estuary | Almost all |
| Sediment conditions in the estuary | Almost all |
| Water quantity issues (i.e., altered hydrology) in the estuary | Almost all |
| Direct mortality from fisheries | Almost all |
| Reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish | All except Clatskanie, Scappoose, Coweeman, NF Lewis, and Sandy |

* "Almost all" means every population except one in each stratum.

## Recovery Strategy: Coho Salmon

The ESU recovery strategy for coho salmon involves improvements in all threat categories to increase abundance, productivity, diversity, and spatial structure to the point that the Coast, Cascade, and Gorge strata are restored to a high probability of persistence. The ESU recovery strategy has seven main elements:

1. Protect and improve populations that have a clear record of continuous natural spawning and are likely to retain local adaptation (the Clackamas and Sandy), along with populations where there is documented natural production (the Clatskanie, Scappoose, and Mill/Abernathy/Germany).

2. Fill information gaps regarding the extent of natural production in other populations, and focus additional recovery efforts on populations that have the greatest prospects for improvement.

3. Protect existing high-functioning habitat for all populations.

4. Restore tributary habitat (particularly overwintering habitat) to the point that each subbasin can support coho salmon at the target status for that population. In most subbasins, this will mean having adequate habitat to support a viable population.

5. Reduce hatchery impacts on natural-origin fish so that impacts are consistent with the target status of each population. (The Grays/Chinook, Elochoman/Skamokawa, Mill/Abernathy/Germany, Clatskanie, Clackamas, Washougal, and Gorge-stratum populations are targeted for large reductions in hatchery impacts.)

[9] Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.

6. Refine harvest management so that impacts are consistent with population and overall ESU recovery goals.

7. Reestablish naturally spawning populations above tributary dams on the Cowlitz and North Fork Lewis rivers by improving passage at dams and continuing to reintroduce coho salmon in these mid- to high-elevation habitats.

For most coho salmon populations, loss and degradation of tributary habitat are the single largest threat—and where the greatest gains in viability are expected to be achieved. Notable exceptions are the Clackamas, Upper Cowlitz, and Cispus populations. For the Clackamas population, protection of existing well-functioning habitat and reductions in hatchery impacts will play a key role in achieving the target status. The Upper Cowlitz and Cispus populations are projected to benefit greatly from hatchery reintroduction programs and dam passage improvements designed to restore their access to key historical spawning and rearing habitats. However, significant tributary habitat protection and restoration efforts also will be necessary for these populations. In most cases, population recovery objectives cannot be achieved without substantial improvements in habitat, even when the impacts of other, non-habitat threats are practically eliminated.

Although recent actions have substantially reduced coho salmon harvest levels from baseline conditions, further refinements in harvest management are still needed. Reductions in hatchery impacts are called for in all strata because hatchery impacts remain significant for many populations.

## Recovery Analysis: Lower Columbia River Chinook Salmon

This recovery plan covers all naturally spawned Chinook salmon (*Oncorhynchus tshawytscha*) populations in the lower Columbia River and its tributaries, from the mouth of the Columbia upstream to the Hood River (in Oregon) and the White Salmon River (in Washington), including the Willamette River up to Willamette Falls but excluding Clackamas River spring-run Chinook salmon.[10] Chinook salmon from 20 hatchery programs also are part of the ESU.[11]

Historically, the Lower Columbia River Chinook salmon ESU consisted of a total of 32 independent populations: 21 fall populations, two late-fall populations, and nine spring populations. These classifications are based on when adults return to fresh water. Spring and late-fall Chinook salmon are "stream-type" salmon, meaning that they generally rear in the river for a full year before emigrating to the ocean. Returning spring Chinook salmon adults spawn primarily in upstream, higher elevation portions of large subbasins. Fall Chinook display an "ocean-type" life history, meaning that juveniles begin emigrating downstream at 1 to 4 months old and make extensive use of

[10] Clackamas River spring Chinook salmon are part of the Upper Willamette River Chinook ESU.

[11] One of these programs—the Elochoman tule fall Chinook salmon program—was discontinued in 2009. In its 2011 5-year review, NMFS recommended that this program be removed from the ESU and that four new fall Chinook salmon programs be added. The new programs are changes in release locations for fish produced at—and previously released from—hatchery programs that are currently part of the ESU.

the Columbia River estuary before entering the ocean. Returning fall Chinook spawn in moderate-sized streams and large river mainstems.

Fall Chinook are commonly referred to as "tule" stock, while late-fall Chinook are referred to as "brights."

### Baseline and Target Status: Chinook Salmon

Today, only two of 32 historical populations—the North Fork Lewis and Sandy late-fall populations—are considered viable. Most populations (26 out of 32) have a very low probability of persistence over the next 100 years, and some populations are extirpated or nearly so. Five of the six strata fall significantly short of the WLC TRT criteria for viability. One stratum—Cascade late fall—meets the WLC TRT criteria.

**Table ES-6**
*Baseline and Target Status* of LCR Chinook Salmon Populations*

| Stratum | Population | Core or Genetic Legacy?** | Contribution to Recovery | Baseline Status | Target Status |
|---|---|---|---|---|---|
| Cascade | Upper Cowlitz (WA) | C, GL | Primary | VL | H+ |
| spring | Cispus (WA) | C | Primary | VL | H+ |
| | Tilton (WA) | | Stabilizing | VL | VL |
| | Toutle (WA) | | Contributing | VL | M |
| | Kalama (WA) | | Contributing | VL | L |
| | NF Lewis (WA) | C | Primary | VL | H |
| | Sandy (OR) | C, GL | Primary | M | H |
| Gorge | White Salmon (WA) | C | Contributing | VL | L+ |
| spring | Hood (OR) | | Primary | VL | VH |
| Coast | Youngs Bay (OR) | | Stabilizing | L | L |
| fall | Grays/Chinook (WA) | | Contributing | VL | M+ |
| | Big Creek (OR) | C | Contributing | VL | L |
| | Elochoman/Skamokawa (WA) | C | Primary | VL | H |
| | Clatskanie (OR) | | Primary | VL | H |
| | Mill/Abernathy/Germany (WA) | | Primary | VL | H |
| | Scappoose (OR) | | Primary | L | H |
| Cascade | Lower Cowlitz (WA) | C | Contributing | VL | M+ |
| fall | Upper Cowlitz (WA) | | Stabilizing | VL | VL |
| | Toutle (WA) | C | Primary | VL | H+ |
| | Coweeman (WA) | GL | Primary | L | H+ |
| | Kalama (WA) | | Contributing | VL | M |
| | Lewis (WA) | GL | Primary | VL | H+ |
| | Salmon Creek (WA) | | Stabilizing | VL | VL |
| | Clackamas (OR) | C | Contributing | VL | M |
| | Sandy (OR) | | Contributing | VL | M |
| | Washougal (WA) | | Primary | VL | H+ |
| Gorge | Lower Gorge (WA & OR) | | Contributing | VL | M |
| fall | Upper Gorge (WA & OR) | C | Contributing | VL | M |
| | White Salmon (WA) | C | Contributing | VL | M |
| | Hood (OR) | | Primary | VL | H |

| Stratum | Population | Core or Genetic Legacy?** | Contribution to Recovery | Baseline Status | Target Status |
|---|---|---|---|---|---|
| Cascade late fall | NF Lewis (WA) | C, GL | Primary | VH | VH |
| | Sandy (OR) | C, GL | Primary | H | VH |

* Status is equivalent to persistence probability. VL = very low, L = low, M = moderate, H = high, VH = very high.

** C = Core populations, meaning those that historically were the most productive. G = Genetic legacy populations, which best represent historical genetic diversity.

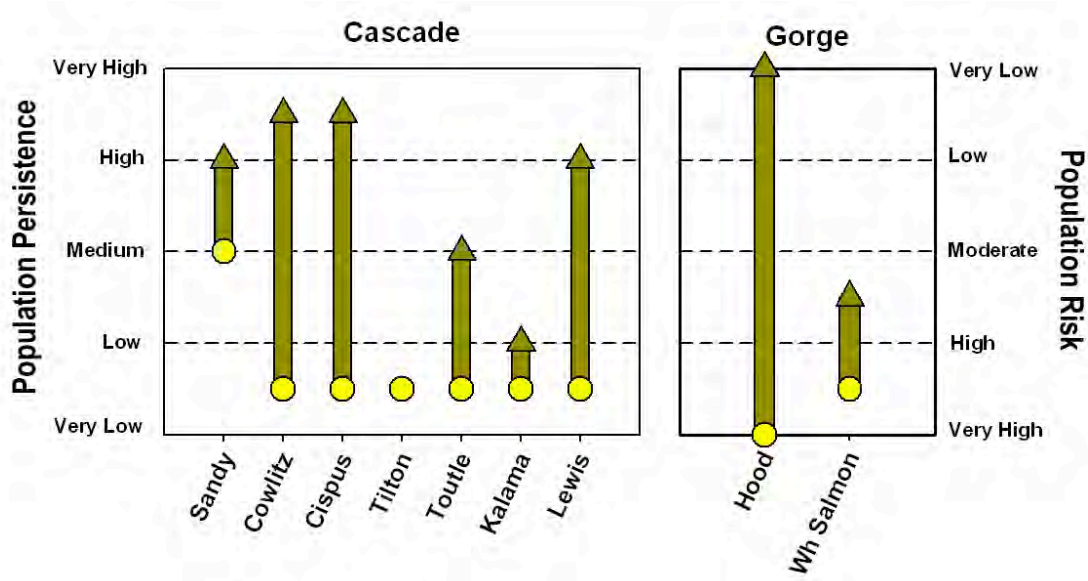


**Figure ES-2.** *Conservation Gaps for LCR Spring Chinook Salmon Populations (i.e., Difference between Baseline and Target Status)*

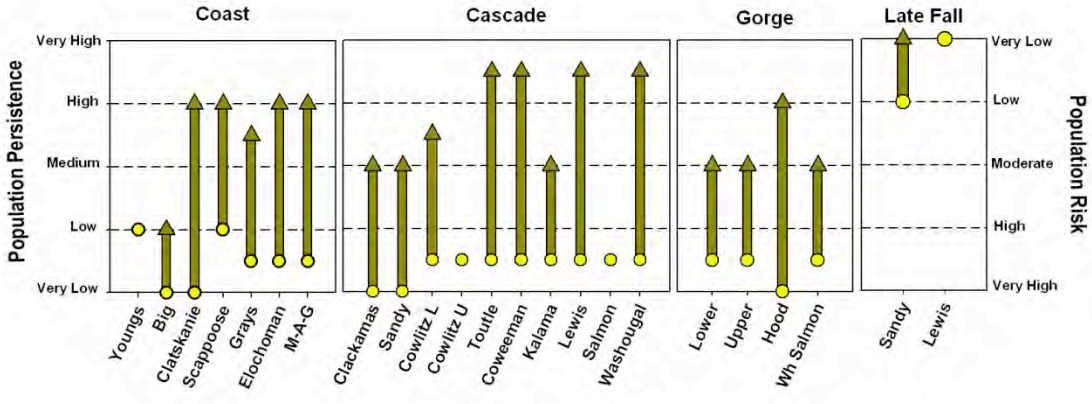


**Figure ES-3.** *Conservation Gaps for LCR Fall and Late-Fall Chinook Salmon Populations (i.e., Difference between Baseline and Target Status)*

## Spring Chinook Recovery Analysis

### *Prevalent Limiting Factors: Spring Chinook Salmon*

Lower Columbia River spring Chinook salmon's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Table ES-7 lists prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

**Table ES-7**
*Prevalent Primary Limiting Factors for Spring Chinook Salmon during Baseline Period*

| Limiting Factor | Populations for Which This Is a Primary Limiting Factor |
|---|---|
| Channel structure and form issues[12] in the Columbia River estuary | Almost all* |
| Sediment conditions in the estuary | Almost all |
| Water quantity issues (i.e., altered hydrology) in the estuary | Almost all |
| Reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish | Almost all |
| Tributary hydropower dams | Upper Cowlitz, Cispus, Tilton, NF Lewis, and White Salmon |
| Direct mortality from fisheries | Upper Cowlitz, Cispus Tilton, Toutle, Kalama, NF Lewis, and Hood |
| Degraded riparian conditions in tributaries | All Cascade-stratum populations |
| Channel structure and form issues in tributaries | All Cascade-stratum populations |
| Impaired side channel and wetland conditions in tributaries | All Cascade-stratum populations |
| Loss/degradation of floodplain habitat in tributaries | All Cascade-stratum populations |

* "Almost all" means every population except one in each stratum.

### *Recovery Strategy: Spring Chinook Salmon*

The recovery strategy for spring Chinook salmon is aimed at restoring the Cascade spring stratum to a high probability of persistence and improving the persistence probability of the two Gorge spring populations. Although the strategy involves threat reductions in all categories, the most crucial elements are as follows:

1. Protect and improve the Sandy spring Chinook salmon population, which is the best-performing population and the only Lower Columbia River spring Chinook salmon population with appreciable natural production. This will be accomplished by protecting high-quality, well-functioning spawning and rearing

[12] Includes channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.

habitat, reducing the proportion of hatchery-origin spawners (pHOS), managing predation, and restoring tributary and estuarine habitat.[13]

2. Reestablish naturally spawning populations above dams on the Cowlitz and North Fork Lewis rivers, in areas that historically were highly productive, by improving adult and juvenile dam passage and developing hatchery reintroduction programs using broodstock from within-subbasin hatchery programs. Reestablishing populations in mid- to upper-elevation habitats is key to recovering the spring component of the Lower Columbia River Chinook salmon ESU.

3. Protect favorable tributary habitat and restore degraded but potentially productive habitat, particularly in the upper subbasins where spring Chinook salmon hold, spawn, and rear. Tributary habitat improvements are crucial for all populations.

4. Reestablish spring Chinook salmon in the White Salmon subbasin (now that Condit Dam has been removed) and in the Hood River subbasin.

Almost every spring Chinook salmon population is greatly affected by the loss and degradation of tributary habitat, and five populations—the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and White Salmon—have experienced impacts from tributary dams that are comparable to or even greater than those associated with degraded tributary habitat. Accordingly, for most populations, the greatest gains in viability are expected from tributary habitat and dam passage improvements (combined with hatchery reintroduction programs). Exceptions are the Tilton—a stabilizing population that is expected to remain at its baseline status—and the Sandy and Hood populations, for which reductions in hatchery impacts are targeted to provide the greatest benefit.

Although recent actions have substantially reduced harvest of spring Chinook salmon from baseline conditions, ancillary and precautionary actions are needed to ensure that harvest does not adversely affect conservation and recovery in the future. For all but the Tilton population, hatchery-related impacts are targeted to be reduced by half or more, with the largest reductions in the Sandy and Hood populations.

## Fall Chinook Recovery Analysis

### *Prevalent Limiting Factors: Fall Chinook Salmon*

Lower Columbia River fall Chinook salmon's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Table ES-8 lists prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

In addition, tributary hydropower dams are a primary limiting factor for the Upper Cowlitz and White Salmon populations, and inundation of historical spawning habitat by Bonneville Reservoir is a primary limiting factor for the Upper Gorge population.

[13] Some reduction in impacts on the Sandy population already have been achieved through removal of Marmot Dam and the Little Sandy River diversion in 2008 and protection of associated instream water rights for fish.

**Table ES-8**
*Prevalent Primary Limiting Factors for Fall Chinook Salmon during Baseline Period*

| Limiting Factor | Populations for Which This Is a Primary Limiting Factor |
|---|---|
| Degraded riparian conditions along tributaries | Almost all* |
| Channel structure and form issues[14] in tributaries and the estuary | Almost all |
| Impaired side channel and wetland conditions in tributaries | Almost all |
| Loss/degradation of floodplain habitat in tributaries | Almost all |
| Loss/degradation of peripheral and transitional habitats[15] in the estuary | Almost all |
| Sediment conditions in the estuary | Almost all |
| Water quantity issues (i.e., altered hydrology) in the estuary | Almost all |
| Direct mortality from fisheries | Almost all |
| Reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish | Almost all |

* "Almost all" means every population except one in each stratum.

### *Recovery Strategy: Fall Chinook Salmon*

The recovery strategy for the tule fall component of the Lower Columbia River Chinook salmon ESU is designed to restore the Coast and Cascade tule strata to a high probability of persistence and to improve the persistence probability of all four Gorge stratum populations. The strategy involves transitioning from decades of management that allowed habitat degradation and emphasized hatchery production of fish for harvest (without adequate regard to effects on natural production) to management that supports a naturally self-sustaining ESU. This transition will be accomplished by addressing all threat categories and sharing the burden of recovery across categories. The most crucial elements are as follows:

1. Protect and improve the Coweeman and Lewis populations, which are currently performing the best, by ensuring that habitat is protected and restored, that the proportion of hatchery-origin spawners (pHOS) is reduced, and that harvest rates allow for gains in productivity to translate into continued progress toward recovery.

2. Fill information gaps regarding the extent of natural production and the extent of hatchery-origin spawners.

[14] Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.
[15] Peripheral and transitional habitats are sloughs, side channels, wetlands, and similar features that are periodically inundated during high flows.

3. Focus recovery efforts on populations that have the greatest prospects for improvement; determine whether efforts to reestablish populations are needed.

4. Protect existing high-functioning habitat for all populations.

5. Implement aggressive efforts to improve the quality and quantity of both tributary and estuarine habitat.

6. Implement aggressive efforts to reduce the influence of hatchery fish on natural-origin fish.

7. Adjust harvest as needed to ensure appropriate increases in natural-origin abundance.

8. Assess habitat quantity, quality, and distribution.

In the Coast and Cascade strata, much of the gains in fall Chinook salmon viability are targeted to be achieved through reductions in harvest, hatchery, and habitat impacts. This is the case for the Grays/Chinook, Elochoman/Skamokawa, Toutle, East Fork Lewis, Sandy, and Washougal populations. For the Scappoose population, target status is expected to be achieved primarily through reductions in hatchery and harvest impacts. In the Gorge stratum, some threat reductions are also targeted from hydropower actions, as the Upper Gorge, White Salmon, and Hood populations have been affected by dam passage issues at Bonneville, Powerdale, and Condit dams. (Powerdale Dam, on the Hood River, was removed in 2010; Condit Dam was breached in October 2011 and completely removed in September 2012).

Impacts from multiple threat categories will need to be reduced for most populations if they are to achieve their target status. Exceptions are the Youngs Bay, Big Creek, Upper Cowlitz, and Salmon Creek populations. As stabilizing populations, the Youngs Bay, Upper Cowlitz, and Salmon Creek populations are not targeted for reductions in any threat impacts. (However, recovery actions will still be needed for these populations to remain at their baseline status of low [for Youngs Bay] or very low persistence probability.) The Salmon Creek population is not targeted for threat reductions because of the highly urbanized nature of the subbasin and the extent of habitat degradation there. Both the Youngs Bay and Big Creek populations will be used to provide harvest opportunity through terminal fisheries targeting hatchery fish; consequently, the proportion of hatchery-origin spawners (pHOS) and harvest impacts in these populations are expected to remain high.

### Late-Fall Chinook Recovery Strategy

#### *Prevalent Limiting Factors: Late-Fall Chinook Salmon*

Table ES-9 lists prevalent limiting factors that the management unit plans identified as having the greatest impact on both late-fall Chinook populations during the baseline period.

**Table ES-9**
*Prevalent Primary Limiting Factors for Late-fall Chinook Salmon during Baseline Period*

| Limiting Factor | Populations for Which This Is a Primary Limiting Factor |
|---|---|
| Sediment conditions in tributaries and the Columbia River estuary | Both populations |
| Water quantity issues (i.e., altered hydrology) in the estuary | Both populations |
| Direct mortality from fisheries | Both populations |

In addition, primary limiting factors that affect the Sandy population only are degraded riparian conditions, channel structure and form issues, impaired side channel and wetland conditions, and loss/degradation of floodplain habitat in tributaries, along with reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish.

### *Recovery Strategy: Late-Fall Chinook Salmon*

The recovery strategy for the late-fall component of the Lower Columbia River Chinook salmon ESU is designed to maintain the two healthy populations (North Fork Lewis and Sandy) and raise the persistence probability of the Sandy population from high to very high. Key elements of the strategy are as follows:

1. Implement the regional hatchery strategy. Minimize the impacts of hatchery releases of steelhead, coho, and spring Chinook salmon on late-fall Chinook salmon. Continue the current practice of not releasing hatchery fall Chinook salmon into the North Fork Lewis River.

2. Reduce harvest impacts on the Sandy late-fall population by using the same harvest strategies identified for tule fall Chinook salmon. Continue to manage fisheries to meet the spawning escapement goal for the Lewis River late-fall population and consider reassessing the goal as new data are acquired.

3. Implement actions in the regional tributary and estuary habitat strategy designed to benefit tule fall Chinook salmon. Implement the stratum-level tributary habitat strategies designated for tule fall Chinook.

Improving the persistence of the Sandy population will be accomplished primarily through reductions in harvest and hatchery impacts. As with spring and tule fall Chinook salmon, recent actions have substantially reduced harvest impacts on late-fall Chinook salmon over baseline conditions, but additional reductions in harvest impacts are identified to achieve the target status for the Sandy population. More modest reductions in the tributary and estuarine habitat, hydropower, and predation threat categories are expected to support the gains achieved through reductions in harvest and hatchery impacts.

## Recovery Analysis: Columbia River Chum

This recovery plan covers all naturally spawned Columbia River chum salmon (*Oncorhynchus keta*) populations in the lower Columbia River and its tributaries. Chum salmon from three hatchery programs also are part of the ESU.[16]

Historically, the Columbia River chum salmon ESU consisted of 17 independent populations. Of these, 16 were fall-run populations and one was a summer-run population that returned to the Cowlitz River. Columbia River chum display an "ocean-type" life history, meaning that fry emigrate downstream shortly after emerging and rear in the Columbia River estuary before entering the ocean. Although chum salmon are strong swimmers, they rarely pass river blockages and waterfalls that pose no hindrance to other salmon or steelhead; thus, they spawn in low-gradient, low-elevation reaches and side channels. Spawning today is restricted largely to tributary and mainstem areas downstream of Bonneville Dam. Chum salmon need clean gravel for spawning, and spawning sites typically are associated with areas of upwelling water.

### Baseline and Target Status: Chum Salmon

Today, 15 of the 17 populations that historically made up this ESU are so depleted that either their baseline probability of persistence is very low or they are extirpated or nearly so; this is the case for all six of the Oregon populations. Currently almost all natural production occurs in just two populations: the Grays/Chinook and the Lower Gorge. All three strata in the ESU fall significantly short of the WLC TRT criteria for viability.

**Table ES-10**
*Baseline and Target Status* of Columbia River Chum Salmon Populations*

| Stratum | Population | Core or Genetic Legacy?** | Contribution to Recovery | Baseline Status | Target Status |
|---|---|---|---|---|---|
| Coast | Youngs Bay (OR) | C | Stabilizing | VL | VL |
| | Grays/Chinook (WA) | C, GL | Primary | M | VH |
| | Big Creek (OR) | C | Stabilizing | VL | VL |
| | Elochoman/Skamakowa (WA) | C | Primary | VL | H |
| | Clatskanie (OR) | | Primary | VL | H |
| | Mill/Abernathy/Germany (WA) | | Primary | VL | H |
| | Scappoose (OR) | | Primary | VL | H |
| Cascade | Cowlitz - fall (WA) | C | Contributing | VL | M |
| | Cowlitz - Summer (WA) | C | Contributing | VL | M |
| | Kalama (WA) | | Contributing | VL | M |
| | Lewis (WA) | C | Primary | VL | H |
| | Salmon Creek (WA) | | Stabilizing | VL | VL |
| | Clackamas (OR) | C | Contributing | VL | M |
| | Sandy (OR) | | Primary | VL | H |
| | Washougal (WA) | | Primary | VL | H+ |

[16] In 2010, the Oregon Department of Fish and Wildlife initiated a new chum salmon hatchery program at Big Creek Hatchery to develop chum salmon for reintroduction into Lower Columbia River tributaries in Oregon. NMFS has not yet evaluated this hatchery program for inclusion in the ESU.

| Stratum | Population | Core or Genetic Legacy?** | Contribution to Recovery | Baseline Status | Target Status |
|---|---|---|---|---|---|
| Gorge | Lower Gorge (WA & OR) | C, GL | Primary | H | VH |
| | Upper Gorge (WA & OR) | | Contributing | VL | M |

* Status is equivalent to persistence probability. VL = very low, L = low, M = moderate, H = high, VH = very high.

** C = Core populations, meaning those that historically were the most productive. G = Genetic legacy populations, which best represent historical genetic diversity.

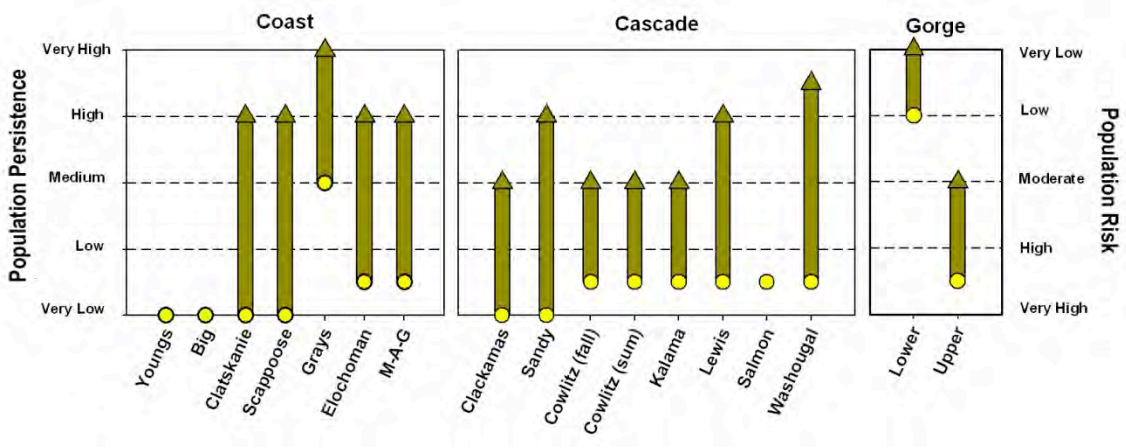


**Figure ES-4.** *Conservation Gaps for Columbia River Chum Salmon Populations (i.e., Difference between Baseline and Target Status)*

## Prevalent Limiting Factors: Chum Salmon

Columbia River chum salmon's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Table ES-11 lists prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

### Table ES-11

*Prevalent Primary Limiting Factors for Chum Salmon during Baseline Period*

| Limiting Factor | Populations for Which This Is a Primary Limiting Factor |
|---|---|
| Channel structure and form issues[17] in the Columbia River estuary | Almost all* |
| Loss/degradation of peripheral and transitional habitats[18] in the estuary | Almost all |
| Sediment conditions in the estuary | Almost all |
| Water quantity issues (i.e., altered hydrology) in the estuary | Almost all |

[17] Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.

[18] Peripheral and transitional habitats are sloughs, side channels, wetlands, and similar features that are periodically inundated during high flows.

| Limiting Factor | Populations for Which This Is a Primary Limiting Factor |
|---|---|
| Degraded riparian conditions in tributaries | Almost all Washington** populations |
| Channel structure and form issues in tributaries | Almost all Washington populations |
| Impaired side channel and wetland conditions in tributaries | Almost all Washington populations |
| Loss/degradation of floodplain habitat in tributaries | Almost all Washington populations |

* "Almost all" means every population except one in each stratum.
** Tributary habitat factors in this table are for Washington populations only because of differences in how Oregon and Washington recovery planners categorized limiting factors occurring in areas of tidal influence in the lower reaches of tributaries; see Table 8-3 of the recovery plan.

In addition, passage issues at Bonneville Dam and inundation of historical spawning habitat by Bonneville Reservoir are identified as primary limiting factors for the Upper Gorge population.

### Recovery Strategy: Chum Salmon

The ESU recovery strategy for Columbia River chum salmon focuses on improving tributary and estuarine habitat conditions, reducing or mitigating hydropower impacts, and reestablishing chum salmon populations where they may have been extirpated. The goal of the strategy is to increase the abundance, productivity, diversity, and spatial structure of chum salmon populations such that the Coast and Cascade chum salmon strata are restored to a high probability of persistence and the persistence probability of the two Gorge populations improves. The ESU recovery strategy has the following main elements:

1. Protect and improve the Grays/Chinook and Lower Gorge populations, which together produce the majority of Columbia River chum salmon and are the only populations in the ESU not currently at very high risk of extinction.

2. Identify, protect, and restore chum salmon spawning habitat in lower mainstem and off-channel areas of large rivers and streams that are fed by upwelling from intergravel flows or springs. Restore hydrologic, riparian, and sediment processes (e.g., large woody debris recruitment) that support the accumulation of spawning gravel and reduce inputs of fine sediment.

3. Restore off-channel and side-channel habitats (alcoves, wetlands, floodplains, etc.) in the Columbia River estuary, where chum salmon fry rely on peripheral and transitional habitats for extended estuarine rearing.

4. Use hatchery reintroduction as appropriate in reestablishing chum salmon populations and continue using supplementation to enhance the abundance of the Grays/Chinook and Lower Gorge populations.

Restoring tributary spawning and estuary rearing habitat is essential in the recovery of Columbia River chum salmon. Although the recovery strategy includes other components, no other factor can effectively bring about recovery.

Most of the gains in the viability of Washington chum salmon populations are targeted to be achieved by improving tributary and estuarine habitat. Because potentially manageable harvest, hatchery, and predation impacts on chum salmon already are relatively low, there is little opportunity to further reduce threats in these sectors. Hydropower actions are projected to benefit the Upper Gorge population, which is affected by Bonneville Dam and its reservoir.

Oregon recovery planners developed a chum salmon recovery strategy that involves identifying specific habitat needs and proceeding with reintroduction, initially in the Coast stratum.

## Recovery Analysis: Lower Columbia River Steelhead

This recovery plan addresses steelhead in the Cascade and Gorge ecozones only, excluding the White Salmon population and populations in the Coast ecozone. This is because the White Salmon population is part of the Middle Columbia steelhead DPS (and thus is addressed in a separate recovery plan), and the Coast populations are part of the Southwest Washington DPS, which is not listed under the ESA. Also excluded is the resident, freshwater form of *Oncorhynchus mykiss*, which usually is called "rainbow" or "redband" trout. In contrast, steelhead are the anadromous form of *O. mykiss*, meaning that they spend a portion of their life cycle in the ocean but return to fresh water to breed. Thus, this recovery plan covers all naturally spawned anadromous *O. mykiss* populations in streams and tributaries to the Columbia River between and including the Cowlitz and Wind rivers in Washington and, in Oregon, between and including (1) the Willamette River up to Willamette Falls, and (2) the Hood River in Oregon. Steelhead from eight hatchery programs also are part of the DPS.[19]

Historically, the Lower Columbia River steelhead DPS consisted of 23 independent populations: 17 winter-run populations and six summer-run populations. Winter and summer steelhead differ in spawning timing, degree of sexual maturity when returning to fresh water, and other characteristics. Both winter steelhead and summer steelhead spawn in a wide range of conditions, from large streams and rivers to small streams and side channels. Within the same watershed, winter and summer steelhead generally spawn in geographically distinct areas. Summer steelhead can often reach headwater areas above waterfalls that are impassable to winter steelhead during the high-velocity flows common during the winter-run migration. Steelhead are iteroparous, meaning they can spawn more than once.

### Baseline and Target Status: Steelhead

Today, 16 of the 23 Lower Columbia River steelhead populations have a low or very low probability of persisting over the next 100 years, and six populations have a moderate

[19] The release of Cowlitz Hatchery winter steelhead into the Tilton River was discontinued in 2007, the Hood River winter steelhead program was discontinued in 2009, and the release of hatchery winter steelhead into the Upper Cowlitz and Cispus rivers was discontinued in 2010. In its 2011 5-year review, NMFS recommended removing these programs from the DPS and adding a Lewis River winter steelhead program that was initiated in 2009.

probability of persistence. Only the summer-run Wind population is considered viable. All four strata in the DPS fall short of the WLC TRT criteria for viability.

**Table ES-12**
*Baseline and Target Status* of LCR Steelhead Populations*

| Stratum | Population | Core or Genetic Legacy?** | Contribution to Recovery | Baseline Status | Target Status |
|---|---|---|---|---|---|
| Cascade summer | Kalama (WA) | C | Primary | M | H |
| | NF Lewis (WA) | | Stabilizing | VL | VL |
| | EF Lewis (WA) | | Primary | VL | H |
| | Washougal (WA) | C | Primary | M | H |
| Gorge summer | Wind (WA) | C | Primary | H | VH |
| | Hood (OR) | | Primary | VL | H |
| Cascade winter | Lower Cowlitz (WA) | | Contributing | L | M |
| | Upper Cowlitz (WA) | C, GL | Primary | VL | H |
| | Cispus (WA | C, GL | Primary | VL | H |
| | Tilton (WA) | | Contributing | VL | L |
| | SF Toutle (WA) | | Primary | M | H+ |
| | NF Toutle (WA) | C | Primary | VL | H |
| | Coweeman (WA) | | Primary | L | H |
| | Kalama (WA) | | Primary | L | H+ |
| | NF Lewis (WA) | C | Contributing | VL | M |
| | EF Lewis (WA) | | Primary | M | H |
| | Salmon Creek (WA) | | Stabilizing | VL | VL |
| | Washougal (WA) | | Contributing | L | M |
| | Clackamas (OR) | C | Primary | M | H |
| | Sandy (OR) | C | Primary | L | VH |
| Gorge winter | L. Gorge (OR & WA) | | Primary | L | H |
| | U. Gorge (OR & WA) | | Stabilizing | L | L |
| | Hood (OR) | C, GL | Primary | M | H |

* Status is equivalent to persistence probability. VL = very low, L = low, M = moderate, H = high, VH = very high.

** C = Core populations, meaning those that historically were the most productive. G = Genetic legacy populations, which best represent historical genetic diversity.

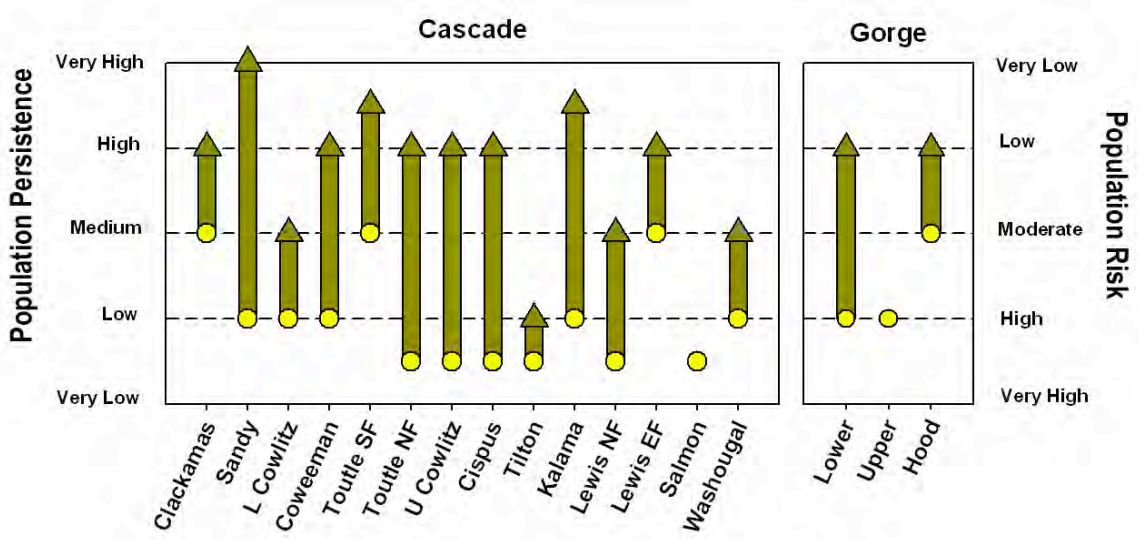


**Figure ES-5.** *Conservation Gaps for LCR Winter Steelhead Populations (i.e., Difference between Baseline and Target Status)*

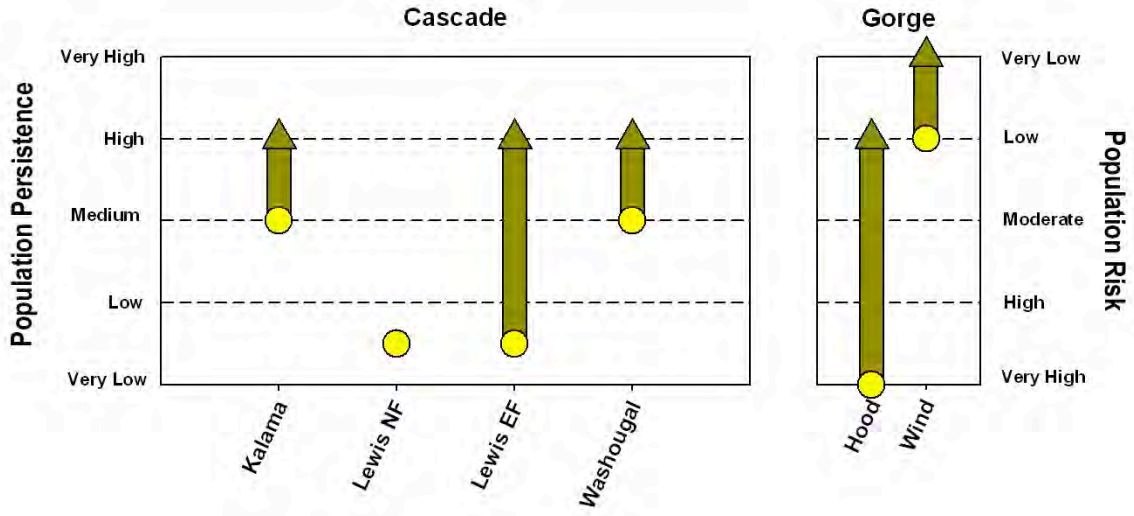


**Figure ES-6.** *Conservation Gaps for LCR Summer Steelhead Populations (i.e., Difference between Baseline and Target Status)*

### Prevalent Limiting Factors: Steelhead

Lower Columbia River steelhead's poor status is due to a host of limiting factors that have affected the ESU for decades, or longer. Tables ES-13 and ES-14 list prevalent limiting factors that the management unit plans identified as having the greatest impact during the baseline period.

**Table ES-13**
*Prevalent Primary Limiting Factors for Winter Steelhead during Baseline Period*

| Limiting Factor | Populations for Which This Is a Primary Limiting Factor |
|---|---|
| Degraded riparian conditions along tributaries | Almost all* |
| Channel structure and form issues[20] in tributaries and the Columbia River estuary | Almost all |
| Impaired side channel and wetland conditions in tributaries | Almost all |
| Loss/degradation of floodplain habitat in tributaries | Almost all |
| Sediment conditions in the estuary | Almost all |
| Water quantity issues (i.e., altered hydrology) in the estuary | Almost all |

* "Almost all" means every population except one in each stratum.

**Table ES-14**
*Prevalent Primary Limiting Factors for Summer Steelhead during Baseline Period*

| Limiting Factor | Populations for Which This Is a Primary Limiting Factor |
|---|---|
| Degraded riparian conditions along tributaries | Almost all* |
| Channel structure and form issues[21] in tributaries | Almost all |
| Impaired side channel and wetland conditions in tributaries | Almost all |
| Loss/degradation of floodplain habitat in tributaries | Almost all |
| Sediment conditions in tributaries and the Columbia River estuary | Almost all |
| Water quantity issues (i.e., altered hydrology) in the estuary | Almost all |

* "Almost all" means every population except one in each stratum.

In addition, tributary hydropower development is a primary limiting factor for the North Fork Lewis summer steelhead population and several populations in the Cascade winter steelhead stratum, as is reduction in population diversity as a result of stray hatchery fish interbreeding with natural-origin fish.

### Recovery Strategy: Steelhead

The recovery strategy for the Lower Columbia River steelhead DPS is aimed at restoring the Cascade and Gorge winter and summer strata to a high probability of persistence. Although the strategy involves threat reductions in all categories, the most crucial elements are as follows:

1. Protect favorable tributary habitat and restore degraded but potentially productive habitat, especially in subbasins where large improvements in

[20] Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.
[21] Includes conditions such as channelization, reduced instream habitat complexity, fill and scour, and associated loss of spawning habitat.

population abundance and productivity are needed to achieve recovery goals. This is the case in the Upper Cowlitz, Cispus, North Fork Toutle, Kalama, and Sandy subbasins for winter steelhead and in the East Fork Lewis and Hood subbasins for summer steelhead.

2. Protect and improve the South Fork Toutle, East Fork Lewis, Clackamas, and Hood winter steelhead populations, which currently are the best-performing winter populations, to a high probability of persistence. This will be accomplished through population-specific combinations of threat reductions, to include protection and restoration of tributary habitat (crucial for all except the Hood population), reductions in hatchery strays on the spawning grounds, and—for the Hood population—removal of Powerdale Dam (this was completed in 2010).

3. Significantly reduce hatchery impacts on the Hood summer steelhead population[22] and, to a lesser degree, on many other populations, especially the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and Clackamas winter populations and the East Fork summer population. Continue to limit hatchery impacts on the Kalama and Wind summer steelhead populations to improve population diversity.

4. Reestablish naturally spawning winter steelhead populations above tributary dams in the Cowlitz system (Upper Cowlitz and Cispus populations) and improve the status of the Tilton winter steelhead population through hatchery reintroductions and comprehensive threat reductions; reintroduce winter steelhead above dams on the North Fork Lewis River.

5. Reduce predation by birds, non-salmonid fish, and marine mammals.

Loss and degradation of tributary habitat, hatchery effects, and predation are pervasive threats that affect most steelhead populations, but the types of recovery actions that will be of most benefit vary by population. For the Upper Cowlitz, Cispus, Tilton, and North Fork Lewis winter populations, the greatest gains are expected to be achieved by reestablishing natural populations above tributary dams, but reductions in hatchery- and tributary habitat-related threats also will contribute significantly. For the East Fork Lewis summer population, improvements in tributary habitat are projected to provide the greatest benefit. The Sandy winter steelhead population is targeted for significant reductions in hatchery-related threats, but because of fairly recent changes in the management of the hatchery steelhead program, current stray rates in this population already are lower than the 10 percent called for for delisting. Hatchery- and tributary habitat-related actions will be of greatest benefit to Clackamas winter steelhead.

In the Gorge strata, reductions in tributary habitat-related threats will be significant for the Lower and Upper Gorge winter populations, especially in Oregon. For the Hood

[22] The Sandy winter steelhead population was also targeted for a significant reduction in hatchery impacts (i.e., 80 percent). However, the Oregon management unit plan states that, because of fairly recent changes in the management of the hatchery steelhead program, current stray rates in the Sandy winter steelhead population already are lower than the 10 percent called for in the threat reduction targets (ODFW 2010 p. 196).

winter population, the greatest gains in persistence probability are expected from reductions in hatchery- and hydropower-related threats. The Hood summer steelhead population is targeted for significant reductions in multiple threat categories, with particularly large reductions in tributary habitat- and hydropower-related threats and a complete elimination of hatchery threats (summer steelhead will no longer be released in the Hood River subbasin).

With harvest impacts on natural-origin winter steelhead having dropped substantially from historical highs, further reductions in harvest impacts do not figure prominently in the threat reduction scenarios for most steelhead populations. The recovery strategy involves continued management of fisheries to limit impacts to baseline levels.

## Adaptive Management and Research, Monitoring, and Evaluation

The life cycles of salmon and steelhead are complex, and there is much we do not know about the range of factors that affect these species and how specific actions influence their characteristics and survival. For this recovery plan to be successful, we must do more than implement the strategies and actions the plan calls for. We also must learn during implementation, continually check our progress in reaching recovery goals, and make adjustments as necessary. Thus, the recovery plan calls for data gathering on the status and trends of populations, their habitats, and sources of threats; resolution of the many unknowns (which are referred to as critical uncertainties); and new or continued research, monitoring, and evaluation (RME) to assess the effectiveness of actions once they are implemented.

The recovery plan also incorporates adaptive management, which is the process of adjusting management actions and/or the overall approach to recovery based on new information, such as information derived from RME activities. Adaptive management works by offering a process for explicitly proposing, prioritizing, implementing, and evaluating alternative approaches and actions. This ensures that the best and most effective means of achieving recovery goals are used, even while scientific understanding of fish populations' needs and the benefits of specific actions continues to change and improve.

Local recovery planners have or will develop specific RME plans—for their respective geographic areas—that are based on regional guidance for adaptive management and RME. These RME plans will guide recovery planning RME efforts and funding in each management unit, within a context of ongoing regional guidance and coordination.

## Implementation

Recovery actions will be implemented over a 25-year period, as specified in the management unit plans and estuary recovery plan module. Effective implementation will require that the recovery efforts of diverse private, local, state, tribal, and federal parties across two states be coordinated at multiple levels.

At the management unit level, Washington's Lower Columbia Fish Recovery Board will lead implementation of actions in southwest Washington, and the Oregon Department of Fish and Wildlife implementation coordinator and stakeholder team will lead

recovery plan implementation in Oregon, supported by the governance structure of the Oregon Plan for Salmon and Watersheds. In the White Salmon, NMFS, in coordination with the Washington Gorge Implementation Team (WAGIT), has taken the lead in coordinating implementation. Each of the lead implementing organizations will develop a series of 3-year or 6-year implementation schedules for their respective management unit. Implementation schedules will identify and prioritize[23] site-specific projects, determine costs and time frames, and identify responsible parties, based on strategies and actions in the recovery plan. Thus, the implementation schedules will provide more detail, clarity, and accountability for implementation than this recovery plan does.

At a higher level than the management units, the Lower Columbia Recovery Planning Steering Committee (which NMFS convened to guide development of this recovery plan) will lead efforts to coordinate the actions of the many entities that will play a role in implementation. For example, there is a need for coordination among the management units and the entities implementing Columbia River estuary recovery actions because the lower, tidal portions of the tributaries, which are within the management unit planning areas, overlap with the planning area of the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead*. The steering committee will perform its coordination functions by working with subcommittees and other regional forums as needed.

Finally, NMFS has a unique role in recovery plan implementation. In addition to ensuring that its statutory responsibilities for recovery under the ESA are met, NMFS will support local recovery efforts by (1) helping to coordinate and encourage recovery plan implementation, (2) using recovery plans to guide regulatory decision making, (3) providing leadership in regional research, monitoring, and evaluation forums, and (4) providing periodic reports on species status and trends, limiting factors, threats, and plan implementation status.

The good news is that some recovery actions already are taking place. Harvest rates have dropped significantly since the first Lower Columbia River species were listed under the Endangered Species Act. Reforms of hatchery practices and programs are being implemented throughout the Columbia Basin. Dams have been removed or breached on the Sandy, Hood, and White Salmon rivers, and improvements in passage and operations to benefit salmon and steelhead are under way at other tributary hydropower facilities and in the Federal Columbia River hydropower system. Tributary and estuary habitat protection and restoration projects are under way. However, considerable additional work is needed to meet the goals of this plan. Habitat activities in particular need to be scaled up if they are to provide the needed benefits.

## Conclusion

Recovery of ESA-listed Lower Columbia River salmon and steelhead will require actions that conserve and restore the key biological, ecological, and landscape processes that support the ecosystems that salmonid species depend on. These measures will require

[23] Some prioritization work already has been done, in that the management unit plans identify high-priority reaches for tributary habitat protection and restoration actions. In addition, the Oregon and White Salmon management unit plans offer some guidance on how actions might be prioritized across threat categories.

implementation of specific tributary and estuary habitat protection and restoration actions; changes in management of harvest, hatchery, and hydropower programs; and predation control. Development of an effective implementation framework, coupled with a responsive RME and adaptive management plan, provides the best assurance that this recovery plan will be fully implemented and effective. The plan's identification of target statuses, primary and secondary limiting factors that have caused gaps between baseline and target status, and actions to close those gaps is intended to aid implementing entities as they take actions that will lead to delisting and, eventually, achievement of broad sense recovery goals. The keys to long-term success will be full funding and implementation of this recovery plan and voluntary participation of residents of the Lower Columbia region. It is only through the involvement of all of those who live and work in this region that recovery will be achieved.

## Key Documents

*Oregon Lower Columbia Conservation and Recovery for Salmon and Steelhead*
Oregon Department of Fish and Wildlife, 2010
http://www.dfw.state.or.us/fish/CRP/lower_columbia_plan.asp

*ESA Recovery Plan for the White Salmon River Watershed*
National Marine Fisheries Service, 2013
http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/lower_columbia_river/lower_columbia_river_recovery_plan_for_salmon_steelhead.html

*Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan*
Lower Columbia Fish Recovery Board, 2010
http://www.lcfrb.gen.wa.us/Recovery%20Plans/RP%20Frontpage.htm

*Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead*
National Marine Fisheries Service, 2011
http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/recovery_plans_supporting_documents.html

*Recovery Plan Module: Mainstem Columbia River Hydropower Projects*
National Marine Fisheries Service, 2008
http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/recovery_plans_supporting_documents.html

2008 Federal Columbia River Power System Biological Opinion and 2010 Supplement
National Marine Fisheries Service, 2008 and 2010
http://www.nwr.noaa.gov/hydropower/fcrps_opinion/federal_columbia_river_power_system.html

# 1. Introduction

This is a plan for the protection and restoration of Lower Columbia River Chinook salmon (*Oncorhynchus tshawytscha*), Lower Columbia River steelhead (*O. mykiss),* Lower Columbia River coho salmon (*O. kisutch*), and Columbia River chum salmon (*O. keta*), all of which are listed as threatened under the Endangered Species Act of 1973 (ESA). These salmon and steelhead, which spawn and rear in the lower Columbia River and its tributaries in Oregon and Washington, are among 19 evolutionarily significant units (ESUs) or distinct population segments (DPSs) of salmon and steelhead in the Pacific Northwest that have been listed as threatened or endangered under the ESA, out of a total of 40 salmon and steelhead ESUs and DPSs in the region.[1] An ESU or DPS is a group of Pacific salmon or steelhead, respectively, that is discrete from other groups of the same species and that represents an important component of the evolutionary legacy of the species. Under the Endangered Species Act, each ESU or DPS is treated as a species.[2]

The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) is required, pursuant to section 4(f) of the Endangered Species Act of 1973, to develop recovery plans for marine species listed under the ESA.[3] Recovery plans identify actions needed to restore threatened and endangered species to the point that they no longer need the protections of the ESA. A recovery plan serves as a road map for species recovery—it lays out where we need to go and how best to get there. Without a plan to organize, coordinate, and prioritize the many possible recovery actions on the part of federal, state, and local governments, tribal agencies, watershed councils and districts, and private citizens, our efforts may be inefficient or even ineffective. Prompt development and implementation of a recovery plan will help target limited resources effectively. Although recovery plans are guidance documents rather than regulatory documents, the ESA envisions recovery plans as the central organizing tool for guiding each species' recovery process. NMFS developed this ESU-level recovery plan by synthesizing material from (1) three geographically based and locally developed recovery plans for Oregon, White Salmon, and southwest Washington populations of Lower Columbia River salmon and steelhead, (2) related recovery plan modules, and (3) additional analyses as appropriate (see Sections 1.5.2 and 1.5.3).

Over the course of their life cycles, Lower Columbia River salmon and steelhead use habitats across a wide geographic range. They spawn and rear in the upper, middle, and lower reaches of freshwater tributaries to the Columbia River and in parts of the Columbia River estuary and lower mainstem. They then migrate as juveniles downstream through the tributaries and mainstem to the estuary and ocean. After

[1] For updates on the number of ESA-listed salmon and steelhead, see the "Snapshot" link at http://www.nwr.noaa.gov/ESA-Salmon-Listings/Salmon-Populations/.

[2] A DPS is defined based on discreteness in behavioral, physiological, and morphological characteristics, whereas the definition of an ESU emphasizes genetic and reproductive isolation. (For a fuller explanation, see Section 1.4.4.)

[3] As anadromous species whose life cycles encompass freshwater, estuarine, and marine ecosystems, salmon and steelhead fall under the jurisdiction of NMFS. Steelhead, which are the migratory form of *Oncorhynchus mykiss,* are distinct from rainbow trout, the resident form of *O. mykiss*. Rainbow trout are under the jurisdiction of the U.S. Fish and Wildlife Service. This recovery plan addresses steelhead and not rainbow trout, as is consistent with the ESA listing decision.

spending years in the ocean, adults migrate back to their natal streams to spawn. The long-term biological success of salmon and steelhead is based on their ability to make use of the diverse habitats from river headwaters to the ocean. Thus, salmon and steelhead's resilience in the face of change depends on maintaining genetic, phenotypic, and behavioral diversity over a wide geographic area.

Human activities have dramatically changed the conditions encountered by Lower Columbia River salmon and steelhead. Although many of the deleterious effects on fish are due to past practices, current human uses of the land and river systems continue to threaten the viability of Lower Columbia River salmon and steelhead across much of their range. In many locations, urban and rural development, agricultural and forest management practices, dredging, and passage obstructions continue to put pressure on salmon and steelhead, whose habitat already has been reduced in amount and quality as a result of extensive loss of channel function and floodplain connectivity. Habitat changes have exacerbated predation by fish, birds, and marine mammals as salmon and steelhead migrate through the lower Columbia River and estuary. Hydropower development has altered river flow, which is a significant force in structuring aquatic and riparian habitats. In addition to eliminating key habitats, hydropower development has altered salmonid food sources, changed freshwater and saltwater balances in the Columbia River estuary, reduced access to habitat in the estuary, and disrupted the timing of salmonid migrations. Harvest mortality of ESA-listed salmon and steelhead occurs in various fisheries—commercial, tribal, and recreational—in the Pacific Ocean, in the lower Columbia River, and in tributaries to the Columbia. Lastly, hatchery-origin fish pose threats in terms of competition, predation, genetic effects, and mixed-stock harvest.

Fortunately, scientific understanding of the threats to Lower Columbia River salmon and steelhead is growing, as is interest in aligning land use, hatchery priorities, harvest practices, and hydropower operations with conservation objectives for salmon and steelhead. More people now recognize the opportunities and benefits of actively protecting and restoring stream corridors, wetlands, stream flows, and other natural features that support native fish and wildlife populations. Management of upland areas is changing to protect or restore watershed function, and cities are undertaking urban watershed protection and restoration. Recovery planning is an opportunity to search for common ground, to organize protection and restoration of salmonid habitat, to reduce other threats to the species, and to secure the economic and cultural benefits that accrue to human communities from healthy watersheds and rivers.

The primary goal of ESA recovery plans is for species to reach the point at which they no longer need the protection of the Endangered Species Act and thus can be delisted. With salmon and steelhead, the final recovery plan is based on locally developed recovery plans. These plans address not just delisting but also local interests and needs based on social, economic, and ecological values. To address these interests, local recovery planners have included "broad sense goals" that go beyond the requirements for delisting. Although the broad sense goals in the locally produced salmon and steelhead recovery plans may be stated in slightly different ways, they usually share some combination of the following elements: ensuring long-term persistence of viable populations of naturally produced salmon and steelhead distributed across their native range, enjoying the social and cultural benefits of meaningful harvest opportunities that

are sustainable over the long term, and pursuing salmon recovery using an open and cooperative process that respects local customs and benefits local communities and economies.

The broad sense goal of ensuring the long-term persistence of viable populations of naturally produced salmon and steelhead distributed across their native range is consistent with ESA delisting, and NMFS' approach to recovery planning has been to use open and collaborative processes with extensive local engagement. NMFS is supportive of the broad sense recovery goals in locally developed plans and believes that the most expeditious way to achieve them is by achieving viability of natural populations and delisting. Upon delisting, NMFS will work with co-managers and local stakeholders, using our non-ESA authorities, to pursue broad sense recovery goals while continuing to maintain robust natural populations. Recovery goals and delisting criteria are discussed in more detail in Chapter 3.

## 1.1 ESA Requirements

Section 4(f) of the ESA requires that a recovery plan be developed and implemented for each species listed as endangered or threatened under the statute.

ESA section 4(a)(1) lists factors for delisting that are to be addressed in recovery plans:

A. The present or threatened destruction, modification, or curtailment of the species' habitat or range
B. Over-utilization for commercial, recreational, scientific, or educational purposes
C. Disease or predation
D. The inadequacy of existing regulatory mechanisms
E. Other natural or human-made factors affecting the species' continued existence

ESA section 4(f)(1)(B) directs that recovery plans, to the extent practicable, incorporate all of the following:

1. A description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species

2. Objective, measurable criteria which, when met, would result in a determination … that the species be removed from the list

3. Estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal

In addition, it is important for recovery plans to provide the public and decision makers with a clear understanding of the goals and strategies needed to recover a listed species and the science underlying those goals and strategies (NMFS 2004a).

Once a species is deemed recovered and therefore removed from the list, section 4(g) of the ESA requires monitoring of the species for a period of not less than 5 years to ensure that it retains its recovered status.

## 1.2 How NMFS Intends to Use the Plan

Although recovery plans are not regulatory, they are important tools that help to do the following:

- Provide context for regulatory decisions
- Guide decision making by federal, state, tribal, and local jurisdictions
- Provide criteria for status reporting and delisting decisions
- Organize, prioritize, and sequence recovery actions
- Organize research, monitoring, and evaluation efforts

NMFS will encourage federal agencies and non-federal jurisdictions to take recovery plans under serious consideration as they make the following sorts of decisions and allocate their resources:

- Actions carried out to meet federal ESA section 7(a)(1) obligations
- Actions that are subject to ESA sections 4d, 7(a)(2), or 10
- Hatchery and Genetic Management Plans and permit requests
- Harvest plans and permits
- Selection and prioritization of subbasin planning actions
- Development of research, monitoring, and evaluation programs
- Revision of land use and resource management plans
- Other natural resource decisions at the state, tribal, and local levels

NMFS will emphasize recovery plan information in ESA section 7(a)(2) consultations, section 10 permit development, and application of section 4(d) rules by considering the following:

- The importance of affected populations to listed species' viability
- The importance of the action area to affected populations and species' viability
- How LFs identified in recovery plans inform analysis of the effects of the action on critical habitat
- The relation of the action to recovery strategies and management actions
- The relation of the action to the research, monitoring, and evaluation plan for the affected species

In implementing these programs, recovery plans will be used as a reference and a source of context, expectations, and goals. NMFS staff will encourage the federal "action agencies" to describe in their biological assessments how their proposed actions will affect specific populations and limiting factors identified in the recovery plans, and to describe any mitigating measures and voluntary recovery activities in the action area.

## 1.3 Geographic Setting

With few exceptions, this recovery plan covers naturally produced and some artificially propagated salmon and steelhead in the Lower Columbia recovery subdomain, meaning the area that is drained by the streams and rivers in the lower Columbia Basin. This includes the Columbia River estuary and lower mainstem, the lower Willamette River below Willamette Falls, and all Columbia River tributaries downstream from and

including the White Salmon River in Washington and the Hood River in Oregon. The plan does not cover steelhead populations in tributaries downstream of the Willamette River in Oregon and the Cowlitz River in Washington (these are part of the Southwest Washington steelhead DPS, which is not ESA listed),[4] steelhead in the White Salmon and Little White Salmon rivers (which are part of the Middle Columbia DPS),[5] salmon and steelhead populations in the upper Willamette River and its tributaries (which are part of the Upper Willamette ESU), and spring Chinook salmon in the Clackamas River (also part of the Upper Willamette ESU). Listed ESUs in the upper Willamette are addressed in a separate recovery plan.

### 1.3.1 Topography and Ecological Zones

The lower Columbia Basin is geographically and ecologically diverse. Draining 8,200 square miles, it spans parts of two states and two mountain ranges: the Coast Range and the Cascades. Elevations range from sea level (at the mouth of the Columbia River) to 14,410 feet (at the summit of Mt. Rainier). Topography includes low-elevation tidally influenced floodplains, which are where most of the urban and agricultural development has occurred. Higher elevations are characterized by alluvial valleys; steep, heavily timbered mountains; and volcanic peaks, specifically Mounts Rainier, St. Helens, and Adams in Washington and Mt. Hood in Oregon. Over geologic time the watersheds of the lower Columbia Basin have been shaped by volcanic, glacial, and alluvial processes, such as flooding, erosion, and sedimentation, and these forces continue to influence habitat conditions. As an example, volcanic activity has played a significant role in structuring habitat as recently as 1980, when Mount St. Helens erupted. Together, the various habitats in the region—from tidal marshes to high-elevation coniferous forests—support more than a dozen fish and wildlife species that are officially threatened, endangered, or of other special conservation concern.

For purposes of salmon and steelhead recovery planning, the lower Columbia Basin is divided into three ecological zones—Coast Range, Cascade, and Columbia Gorge—that were adapted in part from the U.S. Environmental Protection Agency's ecoregions (Omernik 1987, Myers et al. 2006). Ecological zones delineate major geographic areas within the ranges of the ESUs and DPS that have distinct environmental characteristics, such as elevation, soil type, vegetative land cover, rainfall, and climate. Each ecological zone spans the Columbia River and includes parts of both Oregon and Washington.

The individual subbasins in each ecological zone are shown in Table 1-1.

[4] Steelhead populations within the Coast ecozone are addressed, however, in the Oregon and Washington management unit plans to address state planning needs.

[5] The White Salmon and Little White Salmon steelhead populations are addressed in a separate species-level recovery plan, the *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan* (NMFS 2009a). However, recovery actions for the White Salmon population of Mid-Columbia steelhead are included in the White Salmon management unit plan (*ESA Recovery Plan for the White Salmon River Watershed,* NMFS 2013; see Appendix C of this recovery plan) because this population shares geography with Lower Columbia River coho and Chinook salmon and Columbia River chum in the White Salmon subbasin.

**Table 1-1**
*Lower Columbia Subbasins, by State and Ecological Zone*

| Ecological Zone | Oregon Subbasins | Washington Subbasins |
|---|---|---|
| Coast Range | Youngs Bay<br>Big Creek<br>Clatskanie<br>Scappoose | Estuary tributaries: Chinook, Wallacut, and Deep<br>Grays<br>Elochoman<br>Skamakowa<br>Mill, Abernathy, and Germany creeks |
| Cascade | Clackamas<br>Sandy | Cowlitz (Lower Cowlitz, Upper Cowlitz, Cispus, Tilton)<br>Coweeman<br>Toutle<br>Kalama<br>North Fork Lewis<br>East Fork Lewis<br>Salmon Creek<br>Washougal |
| Gorge | Lower Gorge and Upper Gorge tributaries (divided by Bonneville Dam)<br>Hood | Lower Gorge tributaries (including Wind and Little White Salmon)<br>Upper Gorge tributaries (above Bonneville Dam)<br>White Salmon |

Ecological zones are considered a meaningful structure to use in recovery planning because salmon and steelhead populations in different zones exhibit differences in life history characteristics. In addition, given the different climates, geology, and ecological processes in each zone, populations in different zones are unlikely to be affected by the same catastrophic event.

### 1.3.2 Climate

The lower Columbia Basin has a typical Pacific Northwest maritime climate, with cool, dry summers and wet, mild winters. Precipitation patterns are heavily influenced by the Coast and Cascade mountain ranges. In the Coast Range ecological zone, precipitation averages 80 to 95 inches per year, with the vast majority occurring as rain between October and March (Myers et al. 2006). The Cascade zone sees greater variation in precipitation, from 45 to 150 inches annually (Myers et al. 2006). Rain predominates at middle and lower elevations in the Cascade zone, while snow and freezing temperatures are common at high elevations. As in the Coast Range zone, most of the precipitation in the Cascade zone occurs between October and March.

The Columbia Gorge ecological zone has a transitional climate between the high-precipitation area of the Cascades and the drier Columbia Plateau to the east (Myers et al. 2006). Rain shadow effects keep precipitation in the eastern portion of this zone relatively low—to an annual mean of 30 inches in Hood River, Oregon, for example (Western Regional Climate Center 2003). Cooler winter temperatures can occur in this

zone as the result of the influx of cold continental air masses from the east (Welch et al. 2002).

### 1.3.3 Land Uses and Economy

Land uses in the lower Columbia Basin vary from forestry and agriculture to urban and rural residential development. Much of the upper portions of the region's watersheds are forested and managed for timber production. In the Coast Range zone this is usually through private ownership of industrial forests; in the Cascade and Columbia Gorge zones, federal or state ownership of forest land is more common. Within the Cascade zone, forest land in the Coweeman, Toutle, Kalama, lower North Fork Lewis, Salmon Creek, and Washougal subbasins is under predominately state or private ownership, while forest land in the upper Cowlitz, Cispus, Tilton, upper North Fork Lewis, East Fork Lewis, Clackamas, and Sandy subbasins is largely federally owned. Federal ownership in the region includes portions of two national forests (Gifford Pinchot and Mt. Hood), three wilderness areas (Indian Heaven, Salmon-Huckleberry, and Mt. Hood), and other specially managed lands (e.g., Mt. Rainier National Park, Mount St. Helens National Volcanic Monument, and the Columbia River Gorge National Scenic Area).

Large urban and residential zones have developed in lower elevation valley floor areas along the Columbia River and I-5 corridor from Portland, Oregon, to Longview, Washington (LCFRB 2010a). The lower reaches of the Salmon Creek and Clackamas River subbasins, in particular, along with smaller drainages near the city of Portland such as Johnson Creek and Kellogg Creek, are heavily urbanized. High technology, manufacturing, and professional services support the economy of the area's two major population centers: Portland, Oregon (the state's largest city), and Vancouver, Washington (fourth largest city in Washington). Dozens of smaller cities and towns are located in the more rural portions of the region, which has a total human population of more than 2.5 million. Other common land uses in the lower reaches of most subbasins are rural residential development and agriculture, in the form of fruit and vegetable crops, nursery stock, and beef and dairy cattle.

Bonneville is the only dam on the lower mainstem of the Columbia River, but major hydropower or flood control facilities are located on a number of tributaries. Interstate Highway 84, the Union Pacific Railroad line, and the Columbia River constitute a key east-west transportation corridor. Five deep-water ports serve a shipping industry that transports 30 million tons of goods annually. Six major pulp mills contribute to the region's economy and, until the early 2000s, aluminum smelters along the Columbia River produced 40 percent of the country's aluminum. Commercial and recreational fishing continue to support some local communities, and outdoor recreation in general (fishing, wildlife observation, hunting, boating, hiking, and windsurfing) is a growing economic influence.

### 1.3.4 Human Population

An estimated 5 million people live in the Columbia Basin, and many more are expected to move to the area in the coming decades. Population forecasts predict that, by the end of the twenty-first century, between 40 million and 100 million people will be living in the region (National Research Council 2004). Expected population growth rates vary

throughout the area. However, some communities—both urban and rural—can expect their populations to double between 2000 and 2020. Significant growth also is projected for unincorporated areas. In Oregon, particularly fast population growth is predicted in Clackamas, Clatsop, Columbia, Hood River, and Multnomah counties—areas that support Lower Columbia River salmon and steelhead. The population of these counties is expected to increase by 41 percent from 2003 to 2040 (State of Oregon Office of Economic Analysis 2004). In Washington, the populations of Clark and Cowlitz counties are projected to grow by 65 and 53 percent, respectively, from 2000 to 2030 (Washington State Department of Transportation).

## 1.4 Species Covered by the Plan

Of the 19 ESUs or DPSs of salmon and steelhead in the Pacific Northwest that have been listed as threatened or endangered under the ESA, four occur in the lower Columbia Basin and are addressed in this plan: Lower Columbia River Chinook salmon, steelhead, and coho salmon, and Columbia River chum salmon.

Because ESA recovery is predicated on having enough natural production for the ESU to be self-sustaining, natural populations are the primary focus of most of the analyses and recovery actions in this plan. However, NMFS recognizes that in certain circumstances, hatchery populations are closely related to local natural populations and are representative of the genetic legacy of the ESU or DPS in question. NMFS' 2005 hatchery listing policy provides that the agency will include in ESUs or DPSs hatchery programs that are no more than moderately divergent from a natural population that is included in the ESU or DPS (70 *Federal Register* 37204) For this reason, each of the species described below consists of both natural- and hatchery-origin fish.

### 1.4.1 Lower Columbia River Coho Salmon ESU

The Lower Columbia River coho salmon ESU (*Oncorhynchus kisutch*) was listed as threatened under the federal Endangered Species Act on June 28, 2005 (70 *Federal Register* 37160). The ESU includes the following:

- All naturally spawned populations of coho salmon in the lower Columbia River and its tributaries, from the mouth of the Columbia upstream to and including the Hood River (in Oregon) and the White Salmon River (in Washington), and including the Willamette River up to Willamette Falls

- Coho salmon from 25 artificial propagation programs[6]

### 1.4.2 Lower Columbia River Chinook Salmon ESU

The Lower Columbia River Chinook salmon ESU (*O. tshawytscha*) was listed as threatened under the federal Endangered Species Act on March 24, 1999 (64 *Federal Register* 14308). The listing was reaffirmed on June 28, 2005 (70 *Federal Register* 37160).

The Lower Columbia River Chinook salmon ESU includes the following:

[6] For a list of the hatchery programs included in the ESU, along with changes that NMFS proposed in its 2011 5-year review of the ESU's status, see Section 6.1.2.

- All naturally spawned populations of Chinook salmon from the Columbia River and its tributaries from the river's mouth at the Pacific Ocean upstream to and including the Hood River in Oregon and the White Salmon River in Washington, including the Willamette River to Willamette Falls, Oregon, but excluding spring-run Chinook salmon in the Clackamas River[7]

- Chinook salmon from 17 artificial propagation programs[8]

### 1.4.3 Columbia River Chum Salmon ESU

The Columbia River chum salmon ESU (*O. keta*) was listed as threatened on March 25, 1999 (64 *Federal Register* 14507). The listing was reaffirmed on June 28, 2005 (70 *Federal Register* 37160).

The Columbia River chum salmon ESU includes the following:

- All naturally spawned populations of chum salmon in the Columbia River and its tributaries in Oregon and Washington[9]

- Chum salmon from three artificial propagation programs[10]

### 1.4.4 Lower Columbia River Steelhead DPS

"Steelhead" are the anadromous (migratory) form of the biological species *Oncorhynchus mykiss*. Rainbow trout are the non-anadromous (resident) form of *O. mykiss*. NMFS originally listed Lower Columbia River steelhead as threatened on March 29, 1998, under the ESU policy (63 *Federal Register* 13347). NMFS revised the listing on January 5, 2006 (71 *Federal Register* 8844), this time applying the DPS policy (61 *Federal Register* 4722).[11] This recovery plan addresses steelhead only, not rainbow trout (which are under the jurisdiction of the U.S. Fish and Wildlife Service). To avoid confusion, references to ESUs in this recovery plan should be understood to include the steelhead DPS as well.

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[7] Spring Chinook salmon in the Clackamas subbasin are part of the Upper Willamette River spring Chinook ESU. Lower Columbia River coho salmon, chum salmon, steelhead, and fall Chinook salmon also occur in the Clackamas subbasin. For planning purposes, Oregon addressed all the Clackamas populations, including Clackamas River spring Chinook salmon, in its Lower Columbia recovery planning process (ODFW 2010). For ESA purposes, the Clackamas River spring Chinook salmon population is addressed in the *Upper Willamette River Conservation and Recovery Plan for Chinook Salmon and Steelhead* (ODFW and NMFS 2011)

[8] For a list of the hatchery programs included in the ESU, along with changes that NMFS proposed in its 2011 ESA 5-year review, see Section 7.1.2.

[9] The historical upstream boundary for chum salmon is generally considered to have been Celilo Falls, which historically was located approximately where The Dalles Dam is located.

[10] For a list of the hatchery programs included in the ESU, see Section 8.1.2.

[11] The ESA allows listing agencies to list at the level of a species, subspecies, or distinct population segment. For salmon, NMFS applies its ESU policy and treats ESUs as distinct population segments. For steelhead (*O. mykiss*) NMFS shares jurisdiction with the U.S. Fish and Wildlife Service. In 2006, NMFS and the U.S. Fish and Wildlife Service made a determination to apply the DPS policy to *O. mykiss*. The DPS policy recognizes discreteness in behavioral, physiological, and morphological characteristics as contributing to the distinctness of a population segment, whereas the ESU policy emphasizes genetic and reproductive isolation.

Steelhead found within the geographical boundaries of the Lower Columbia recovery subdomain fall into three separate DPSs as defined by NMFS: Lower Columbia, Middle Columbia, and Southwest Washington. The Middle Columbia DPS includes steelhead from the White Salmon and Little White Salmon rivers, while the Southwest Washington DPS includes steelhead from the Grays and Elochoman rivers and Skamakowa, Mill, Abernathy, and Germany creeks in Washington, and from the Youngs Bay, Big Creek, Clatskanie, and Scappoose subbasins in Oregon.

This recovery plan addresses steelhead from the Lower Columbia DPS only, not populations from the Middle Columbia and Southwest Washington DPSs.[12] Specifically, the Lower Columbia River steelhead DPS includes the following:

- All naturally spawned anadromous *O. mykiss* populations below natural and manmade impassable barriers in streams and tributaries to the Columbia River between and including the Cowlitz and Wind rivers in Washington
- All naturally spawned anadromous *O. mykiss* populations below natural and manmade impassable barriers in streams and tributaries to the Columbia River between and including (1) the Willamette River up to Willamette Falls, and (2) the Hood River in Oregon
- Steelhead from 10 artificial propagation programs[13]

## 1.5 Context of Plan Development

This plan is the product of a collaborative process initiated by NMFS that involves the State of Washington, regional salmon recovery organizations within Washington (the Lower Columbia Fish Recovery Board, in particular), the State of Oregon (led by the Oregon Department of Fish and Wildlife, with extensive participation by the Oregon Governor's Natural Resources Office), the Lower Columbia Estuary Partnership, regional stakeholder teams within Oregon, other federal and state agencies, tribal and local governments, representatives of industry and environmental groups, and the public.

While NMFS is directly responsible for ESA recovery planning for salmon and steelhead, the agency believes that ESA recovery plans for salmon and steelhead should

[12] The Mid-Columbia steelhead DPS, which includes the White Salmon population, is addressed in a separate recovery plan, the *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan* (National Marine Fisheries Service [Northwest Region] November 2009). Steelhead in the Youngs Bay, Big Creek, Grays, Elochoman, Skamakowa, Clatskanie, Mill, Abernathy, Germany, and Scappoose watersheds are part of the Southwest Washington DPS, which is not listed under the ESA(61 *Federal Register* 41541). However, these populations are included in the Oregon and Washington management unit plans because their status needs to be improved, they share geographic range and life history traits with the ESA-listed Lower Columbia River species, and they are expected to benefit from recovery actions targeted at the listed species. Similarly, the White Salmon management unit plan (NMFS 2013) covers the White Salmon steelhead population, which is part of the Mid-Columbia DPS, because of this population's shared geography with the White Salmon coho, Chinook, and chum salmon populations, all of which are part of the Lower Columbia River ESUs.

[13] For a list of the hatchery programs included in the DPS, along with changes that NMFS proposed in its 2011 ESA 5-year review, see Section 9.1.2.

be based on the many state, regional, tribal, local, and private conservation efforts already under way throughout the region. Local support of recovery plans by those whose activities directly affect the listed species, and whose actions will be most affected by recovery efforts, is essential. NMFS therefore supports and participates in locally led collaborative efforts to develop recovery plans that involve local communities; state, tribal, and federal entities; and other stakeholders.

NMFS developed this recovery plan with assistance from the Lower Columbia Recovery Plan Steering Committee, a group convened by NMFS (see Chapter 11) to provide input to the ESU-level plan. NMFS developed this plan by drawing upon the best available scientific information provided by three regional recovery plans, related recovery plan modules, the work of the Willamette-Lower Columbia Technical Recovery Team (see below) and technical experts from NMFS, Washington, Oregon, the Yakama Nation, and regional planning groups. The draft plan went through multiple reviews and revisions in response to comments from both technical reviewers and steering committee members and then was further revised in response to comments received during two public review periods in 2012.

### 1.5.1 Recovery Domains and Technical Recovery Teams

Currently, there are 19 ESA-listed ESUs and DPSs of Pacific salmon and steelhead in the Pacific Northwest. NMFS' Northwest Region also shares jurisdiction of an additional ESU—the Southern Oregon/Northern California coho salmon—with the agency's Southwest Region. For the purpose of recovery planning for these species, the Northwest Region designated five geographically based "recovery domains": the Interior Columbia, Willamette-Lower Columbia, Puget Sound, Oregon Coast, and Southern Oregon/Northern California Coast domains (see Figure 1-1). NMFS' Northwest Region delineated these domains by considering ESU or DPS boundaries, ecosystem boundaries, and local planning units.

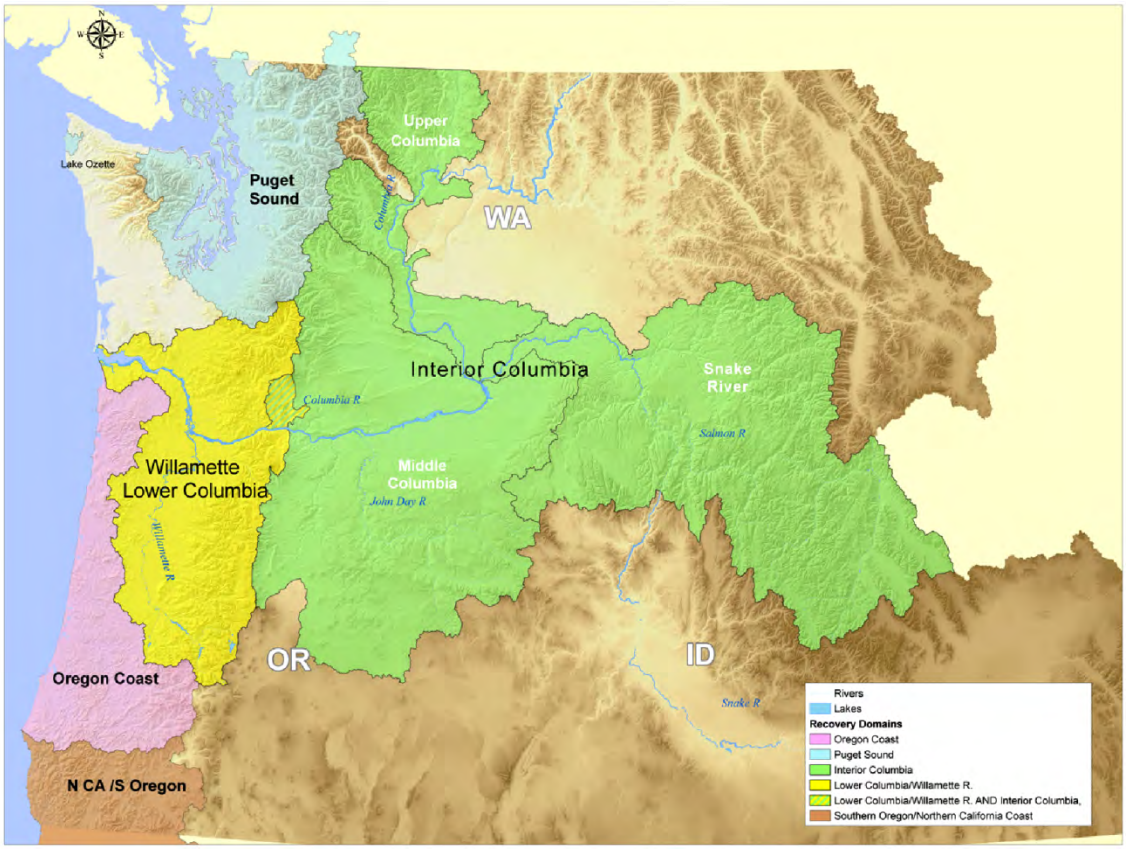


**Figure 1-1.** *NMFS Northwest Region Recovery Domains*

In the case of the Willamette-Lower Columbia domain, the domain was further divided into two subdomains to accommodate different planning processes and timelines. The range of the Lower Columbia River salmon and steelhead ESUs and DPS is within the Lower Columbia subdomain of the Willamette-Lower Columbia domain (see Figure 1-2).

For each domain, NMFS appointed a team of scientists who have geographic and species expertise to provide a solid scientific foundation for recovery plans. The charge of each Technical Recovery Team (TRT) was to define the historical population structure of each ESU or DPS, to recommend biological viability criteria for each ESU or DPS and its component populations, to provide scientific support to local and regional recovery planning efforts, and to provide scientific evaluations of proposed recovery plans. The Willamette-Lower Columbia TRT (WLC TRT) was formed in May 2000 and included representatives from NMFS' Northwest Fisheries Science Center, the Washington Department of Fish and Wildlife (WDFW), the U.S. Fish and Wildlife Service (USFWS), the University of Portland, and a private consultant.

Each TRT used the same biological principles to develop its recommended ESU and population viability criteria; these criteria will be used in combination with criteria based on mitigation of the factors for decline to determine whether a species has recovered sufficiently to be downlisted or delisted. The biological principles that underlie the viability criteria are described in the NMFS technical memorandum *Viable*

*Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). A viable ESU or DPS is naturally self-sustaining over the long term. McElhany et al. describe viable salmonid populations (VSP) in terms of four parameters: abundance, population productivity or growth rate, population spatial structure, and life history and genetic diversity.

Each TRT's recommendations are based on the VSP framework and considerations related to data availability, the unique biological characteristics of the ESU or DPS and the habitats in the domain, and the TRT members' collective experience and expertise. Although NMFS has encouraged the TRTs to develop regionally specific approaches for evaluating viability and identifying factors limiting recovery, each TRT was working from a common scientific foundation to ensure that the recovery plans are scientifically sound and based on consistent biological principles.

TRT recommendations were used by NMFS and local planning groups to develop goals for the recovery plans. As the agency with ESA jurisdiction for salmon and steelhead, NMFS makes final determinations of ESA delisting criteria.

### 1.5.2 Management Units and Integration of Management Unit Plans

In each domain, NMFS collaborates with other federal agencies and state, tribal, and local entities to develop planning forums appropriate to the domain, building to the extent possible on ongoing, locally led recovery efforts. These planning forums use the TRT and other technical resources to agree on recovery goals and limiting factors and then to develop locally appropriate and locally supported recovery actions needed to achieve recovery goals. Although the planning forums were working from a consistent set of assumptions regarding needed recovery plan elements, the process by which they develop those elements—and the form those elements take—may differ among domains.

The structure of recovery planning in the Willamette-Lower Columbia recovery domain, which includes parts of Washington and Oregon, differs in the two states. To accommodate the different planning efforts and jurisdictional boundaries, NMFS partitioned the domain into four management units: Washington (the portion of the Lower Columbia River salmon ESUs and steelhead DPS that occurs within the planning area of Washington's Lower Columbia Fish Recovery Board), White Salmon (the White Salmon subbasin in Washington), Oregon Lower Columbia (the portion of the Lower Columbia River salmon ESUs and steelhead DPS that occurs within Oregon), and Upper Willamette (predominantly the Willamette Basin above Willamette Falls). (See Figure 1-2.)

**Figure 1-2.** *Management Units of the Willamette-Lower Columbia Recovery Domain*

A locally developed recovery plan has been completed for each of these management units. This ESU-level recovery plan is a synthesis of relevant information from three of the management unit plans—Washington, White Salmon, and Oregon Lower Columbia. The three management unit plans and their associated planning processes are described below.

### *1.5.2.1 Washington Management Unit Recovery Plan*

The recovery plan for the Washington management unit covers the portion of the Lower Columbia River salmon ESUs and steelhead DPS that occurs in Washington within the

planning area of the Lower Columbia Fish Recovery Board (LCFRB), which was established by Washington statute in 1998 to oversee and coordinate salmon and steelhead recovery efforts in the lower Columbia region of Washington. The LCFRB comprises representatives from the state legislature, city and county governments, the Cowlitz Tribe, the environmental community, hydroelectric utilities, and concerned citizens.

The LCFRB led and coordinated a collaborative process to develop the Washington management unit plan, titled the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB 2010a). Partners in the planning process included federal agencies, tribal governments, Washington state agencies, regional organizations, and city and county governments. In addition, workshops, presentations, and public comment periods offered opportunities for broader community and public input. The resulting document is an integrated plan that serves planning needs associated with the Endangered Species Act, the Northwest Power and Conservation Council's fish and wildlife subbasin planning process, and state salmon recovery and watershed planning. The plan is intended to protect and restore native fish, aquatic habitats, and sensitive wildlife species in Washington's lower Columbia River watersheds. In February 2006, NMFS approved the December 2004 version of the plan as an interim regional recovery plan for the listed salmon ESUs and steelhead DPS. In May 2010, the LCFRB completed a revision of its earlier plan. This ESU-level recovery plan includes the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB 2010a) as Appendix B.[14]

#### *1.5.2.2 White Salmon Management Unit Recovery Plan*

The recovery plan for the White Salmon management unit covers the portions of the Lower Columbia River Chinook, coho, and chum salmon ESUs that occur in the White Salmon subbasin in Washington. It also covers steelhead in the White Salmon subbasin, which are part of the ESA-listed Middle Columbia River DPS and are addressed in the *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan* (NMFS 2009a).

In the absence of a local planning forum for salmon recovery, NMFS developed the White Salmon management unit recovery plan for ESA-listed salmon and steelhead in the White Salmon subbasin in cooperation with the Yakama Nation, Klickitat County, WDFW, and other stakeholders. The plan, titled *ESA Recovery Plan for the White Salmon River Watershed* (NMFS 2013) is included in this ESU-level recovery plan as Appendix C.[15]

In 2009, NMFS, in coordination with the Yakama Nation, WDFW, U.S. Geological Survey, Klickitat County, Washington Gorge Conservation District, Washington Department of Ecology, and other local groups, established the Washington Gorge Implementation Team to support continued coordination of salmon and steelhead recovery efforts.

[14] The Washington management unit plan is available at http://www.lcfrb.gen.wa.us/default1.htm.
[15] The White Salmon management unit plan is available at www.nwr.noaa.gov.

#### *1.5.2.3 Oregon Lower Columbia Management Unit Recovery Plan*

The recovery plan for the Oregon Lower Columbia management unit covers the portion of the Lower Columbia River salmon ESUs and steelhead DPS that occurs within Oregon. The Oregon Department of Fish and Wildlife (ODFW) led development of this plan in collaboration with NMFS and numerous stakeholders, including other federal agencies, state agencies, local governments, tribes, industry and environmental representatives, and the public. An expert panel, stakeholder team, and planning team provided additional input and guidance. The resulting plan serves both as a federal recovery plan under the ESA and a State of Oregon conservation plan under Oregon's Native Fish Conservation Policy. The plan also influences actions implemented for the Oregon Plan for Salmon and Watersheds, some of which are coordinated by the Oregon Watershed Enhancement Board. This ESU-level plan includes the *Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead* (ODFW 2010) as Appendix A.[16]

#### *1.5.2.4 Relationship Between Management Unit Plans and ESU-Level Plan*

This ESU-level recovery plan for the Lower Columbia River ESUs and DPS is a synthesis of the Washington, White Salmon, and Oregon Lower Columbia management unit plans, additional analyses as appropriate, and related recovery plan modules that address estuary habitat and hydropower (see Section 1.5.3). The ESU-level recovery plan provides an ESU-level perspective on the baseline status of the Lower Columbia River ESUs and DPS, goals and delisting criteria, limiting factors, scenarios for reducing threats, recovery actions, implementation, and research, monitoring and evaluation. As required by the ESA, this ESU-level recovery plan fully addresses the recovery needs of the Lower Columbia River salmon ESUs and steelhead DPS, throughout their life cycle and across their geographic range, which encompasses multiple management units.

The more detailed Washington, White Salmon, and Oregon Lower Columbia management unit recovery plans are part of this ESU-level plan, which includes them as appendices. By doing so, the ESU-level plan endorses the management unit plans' recommendations and acknowledges that certain recovery decisions (such as decisions about site-specific habitat actions) are most appropriately left to local recovery planners and implementers, as represented in the management unit plans. Where there are differences between the ESU-level plan and the management unit plans that affect regulatory decisions, management decisions, and implementation of recovery actions, NMFS will coordinate with the management unit leads (Washington's Lower Columbia Fish Recovery Board, the Oregon Department of Fish and Wildlife, and the Washington Gorge Implementation Team) to resolve those discrepancies.

### 1.5.3 Challenges of Bi-State Coordination and Multiple Management Units

The fact that the Lower Columbia River salmon ESUs and steelhead DPS span two states and three separate management units presents certain challenges in developing an ESU-level recovery plan. First, the sheer volume of information generated through three

[16] The Oregon management unit plan is available at http://www.dfw.state.or.us/fish/CRP/lower_columbia_plan.asp.

separate planning processes is large. This ESU-level plan selects the most relevant information from the three management unit plans to present a coherent overview of the baseline status and potential future of the listed ESUs and DPS; where appropriate, the document refers the reader to more detailed information available in the individual management unit plans.

Second, the level of effort needed to recover the listed ESUs and DPS also is large, and how the responsibility for achieving recovery is apportioned between Oregon and Washington has significant financial and organizational implications for implementing entities in each state. Early in the recovery planning process, management unit planners decided to share the recovery burden between the two states. However, they agreed that in doing so they would consider the historical proportion of populations in each state and where the prospects for recovery are most promising (LCFRB 2010a). Thus, for some ESUs the burden of recovery falls more heavily on one side of the Columbia River than the other. For example, Washington carries the greatest burden in recovering tule fall Chinook salmon, in part because most of the historical fall Chinook salmon populations were in Washington.

Third, the three management unit planning teams took different approaches to developing their recovery plans, in part because different salmon recovery planning structures are in place in Oregon and Washington but also because NMFS encourages recovery plans to be locally developed and supported. This naturally leads to unique approaches. Although each management unit plan contains the elements required for a recovery plan and draws on common scientific principles and resources provided by the WLC TRT, the specific approaches used to develop the required elements, and sometimes the results, varied among the management unit plans. Where relevant, this ESU-level plan acknowledges and describes the differences in approaches and results and discusses the implications of those differences.

Fourth, given the complexity of the salmonid life cycle, some regional issues that affect the Lower Columbia River ESUs and DPS are beyond the scope of any one management plan. Examples include the Federal Columbia River Power System (FCRPS) and the role of the Columbia River estuary in the life cycle of the listed ESUs and DPS. Such issues need to be addressed at the regional level. Thus, NMFS developed the following recovery plan modules that analyze regional issues:

- *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a; see Appendix D.) The estuary document focuses on habitat in the lower Columbia River below Bonneville Dam and how it affects the survival of ESA-listed, coho, Chinook, chum, and steelhead from throughout the Columbia Basin, including the Lower Columbia River ESUs and DPS. Geographically, the module covers the tidally influenced reaches of the lower river, estuary, and plume. The module identifies and prioritizes limiting factors and threats in the estuary that affect salmonid viability and describes 23 broad actions that, if implemented, would increase the survival of salmon and steelhead during their time in the estuary and plume. Costs, implementation considerations, and research, monitoring, and evaluation needs also are addressed. The actions and recommendations in the estuary module have been incorporated into this ESU-level recovery plan for the Lower Columbia River salmon ESUs and steelhead DPS.

- *Recovery Plan Module: Mainstem Columbia River Hydropower Projects* (NMFS 2008a; see Appendix E.) The hydropower module summarizes the general effects of Columbia River mainstem hydropower projects on all 13 ESA-listed anadromous salmonids in the Columbia Basin. The module's geographical area consists of the accessible mainstem habitat in the upper Columbia River (to the tailrace of Chief Joseph Dam) and Snake River (to the tailrace of Hells Canyon Dam) and downstream to the tailrace of Bonneville Dam. The module describes how salmon and steelhead use the mainstem, habitat limiting factors and threats related to mainstem hydropower projects and operations, and expected actions (including site-specific management actions) or strategy options to address those threats. The actions are those found in the 2008 Federal Columbia River Power System Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a), which constitute mitigation and recovery actions for the FCRPS through 2018. The hydropower module presents recent survival estimates for ESA-listed populations migrating past mainstem hydroelectric project, and prospective passage survival rates for juveniles for 2014 and beyond.

The estuary and hydropower recovery plan modules provided a consistent set of assumptions and recovery actions for regional-scale issues that management unit planning teams then incorporated into their management unit plans. Additional bi-state consultation and coordination were needed to ensure consistent treatment of hydropower and estuary issues across the management unit plans, as well as of hatchery and harvest issues. Chapter 4 presents additional information on regional-scale limiting factors and recovery strategies.

Topics such as implementation, monitoring, adaptive management, and funding priorities also have both local-scale and regional aspects. This ESU-level recovery plan presents a regional perspective on such topics. Again, considerable bi-state consultation and coordination were needed to integrate these topics across the individual management plans and to develop a regional perspective and approach for the ESU-level recovery plan.

### 1.5.4 Challenges of Addressing Multiple ESUs/DPSs in a Single Recovery Plan

Preparing a single recovery plan for multiple ESUs presents challenges in terms document organization, level of detail, and prioritization of actions. In some cases, the same limiting factors and threats affect more than one ESU, and the species-specific recovery strategies have the same or similar components. For example, for each ESU the management unit plans propose some similar tributary habitat actions to improve watershed health overall, which will benefit every ESU. In other cases the limiting factors, threats, and recovery actions are unique to an ESU or a run component of a species. To avoid unnecessary repetition from one species analysis to the next, this ESU-level recovery plan includes a chapter on regional-scale limiting factors and recovery strategies; this information applies to multiple ESUs. When appropriate, the individual species analyses refer readers to the regional chapter (Chapter 4) instead of repeating the same or similar recovery strategy information from one ESU to the next. This is the case with watershed-based tributary habitat actions, the estuary habitat strategy, mainstem hydropower actions, the predation strategy, and certain elements of the harvest and hatchery strategies.

Given the large amount of information available in three management unit plans on four different species, another (and related) challenge is to present relevant material at the appropriate level of detail in the ESU-level recovery plan. To maintain a cohesive narrative while not overwhelming the reader, this plan presents some information at a relatively abstract, summary level, with the understanding that readers will refer to the management unit plans for additional detail as their needs and interests dictate.

Lastly, addressing multiple ESUs in a single plan raises the question of how recovery actions will be prioritized across ESUs. This is an issue that the management unit plans, for the most part, did not explicitly address, although they did offer some guidance on the topic. As described in Section 11.2, additional prioritization work is needed at both the management unit and subdomain levels, both within and among threat categories. Section 11.2 discusses prioritization in more detail, summarizing the management unit plans' approaches and offering perspectives for potential consideration during implementation of this recovery plan.

### 1.5.5 Relationship to Other Processes

Development of this ESU-level recovery plan has been informed by many different conservation and recovery planning processes in Oregon, Washington, and the Pacific Northwest region. Some of these planning processes have been completed, but many are still under way and will continue to influence the content of this recovery plan as it is finalized, along with its implementation in the Lower Columbia subdomain. Planning efforts that have a significant bearing on the design or implementation of this recovery plan are described below.

#### *1.5.5.1 Willamette-Lower Columbia ESA Executive Committee (Ex Com)*

The Willamette-Lower Columbia ESA Ex Com performed a coordinating role during the early stages of recovery planning for this domain. Members included the Oregon and Washington Departments of Fish and Wildlife, the governors' offices of Oregon and Washington, federal agencies, the Lower Columbia Estuary Partnership, the Lower Columbia Fish Recovery Board, and the Willamette Partnership. During its tenure, the Ex Com worked to help align ongoing regional, state, and local processes with recovery planning; address bi-state and tribal coordination issues; develop agreement on recovery goals and other elements of recovery plans; ensure adequate integration of scientific information with recovery actions and strategies; and ensure that locally developed management unit plans address the needs of the full ESUs or DPSs.

#### *1.5.5.2 Northwest Power and Conservation Council Subbasin Plans*

Congress created the Northwest Power and Conservation Council (NPCC) in 1980 to give Washington, Oregon, Idaho, and Montana a voice in regional energy planning and in mitigating the effects of the Federal Columbia River Power System on fish and wildlife. The NPCC developed the Columbia Basin Fish and Wildlife Program, which solicits and evaluates proposals for on-the-ground projects and research to meet these responsibilities. The Bonneville Power Administration (BPA) provides funding for NPCC-identified priority projects. In 2005, to update the Columbia Basin Fish and Wildlife Program, the NPCC completed a watershed planning effort that resulted in

locally developed plans for 58 of 62 designated subbasins (tributary watersheds or mainstem segments) in the Columbia Basin, including subbasins within the geographic range of the Lower Columbia River salmon ESUs and steelhead DPS. The plans address the needs of both fish and wildlife.

The subbasin plans provide valuable information on watershed-scale freshwater habitat conditions, limiting factors, and threats, as well as strategies at a subbasin level for addressing those limiting factors and threats. NMFS and its planning partners are using subbasin plans as building blocks for ESA salmon and steelhead recovery plans, and information from the Lower Columbia, White Salmon, Columbia Gorge, Hood, and Willamette subbasin plans has been incorporated into this ESU-level recovery plan. NMFS will continue to work with the NPCC and BPA to coordinate implementation of the Columbia Basin Fish and Wildlife program and ESA salmon recovery plans.

#### *1.5.5.3 2008 FCRPS Biological Opinion and 2010 Supplement*

As described in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) and elsewhere, a limiting factor for Lower Columbia River salmon and steelhead during their time in the Columbia River estuary and, potentially, the plume is flow regulation and other effects related to the Federal Columbia River Power System (FCRPS) and non-federal Columbia and Snake River dams. The FCRPS is a series of dams and reservoirs that are managed for multiple purposes: power production, flood control, irrigation, navigation, recreation, and fish, wildlife, and cultural resource protection. Dam-related alterations of natural flow patterns in the lower Columbia River, estuary, and plume are responsible for decreased water velocity, longer migratory travel time (which increases exposure to predators) and higher water temperatures during the spring freshet. Each of these factors is associated with mortality of ESA-listed salmon and steelhead.

The ESA requires that federal actions neither jeopardize the continued existence of a listed species nor result in destruction or adverse modification of designated critical habitat. Under law, the agencies that operate the FCRPS—the Bonneville Power Administration, U.S. Army Corps of Engineers, and Bureau of Reclamation (collectively referred to as the Action Agencies)—must consult with NMFS on proposed FCRPS operations that may affect a listed fish species or its habitat. The product of such consultation is a Biological Opinion.

In preparation for NMFS' 2008 Biological Opinion on the FCRPS, the Action Agencies concluded that, without further mitigation, operation of FCRPS projects would jeopardize listed species. Consequently, the Action Agencies presented NMFS with a package of additional measures designed to benefit listed species, including the Lower Columbia River salmon ESUs and steelhead DPS. Some of these actions were drawn from the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NOAA Fisheries 2009), which describes the FCRPS's effects on fish and presents recommendations and strategies for action. NMFS incorporated the Action Agencies' proposed additional mitigation measures into its analysis for the 2008 FCRPS Biological Opinion, which considers the mainstem Columbia from Bonneville Dam to the river's mouth.

The 2008 FCRPS Biological Opinion was issued on May 5, 2008. In February 2010, NMFS issued the 2010 Supplemental Biological Opinion for the FCRPS (NMFS 2010a). This Supplemental Biological Opinion integrated elements from the 2008 Biological Opinion and the Adaptive Management Implementation Plan (AMIP). The AMIP included accelerated and enhanced actions to protect Columbia Basin salmon and steelhead, including commitments to additional estuary habitat improvement actions under a new agreement with the state of Washington and additional efforts to control native and exotic predators. It also included enhanced research and monitoring and specific biological triggers for contingencies linked to unexpected declines in the abundance of listed salmon and steelhead.

At the time this recovery plan was being drafted, it was the position of the State of Oregon that additional or alternative actions should be taken in mainstem operations of the FCRPS for ESA-listed salmon and steelhead. Some additional or alternative actions recommended by Oregon, while considered, were not included in NMFS' 2008 FCRPS Biological Opinion and its 2010 Supplement because NMFS is not in agreement regarding the need for or efficacy of these additional actions. At this time, Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of the measures contained in the current FCRPS Biological Opinion. On August 2, 2011, Judge James A. Redden of the U.S. District Court (District of Oregon) issued an opinion and order that remanded the 2008 Biological Opinion and its 2010 Supplement back to NMFS. Judge Redden left the Biological Opinion in place until a new opinion is issued no later than January 1, 2014, and ordered that all of the opinion's mitigation measures be funded and implemented in that time.

#### *1.5.5.4 Columbia River Hatchery Scientific Review Group (HSRG)*

In 2005, Congress directed NMFS to use the Puget Sound and coastal Washington hatchery reform project as a model for similar reform in the Columbia Basin. The Columbia River Hatchery Scientific Review Group (HSRG) conducted a collaborative, scientific review and identified alternatives for managing hatchery programs and fisheries to meet managers' goals for harvest and recovery (Hatchery Scientific Review Group 2009).

The HSRG concluded that hatcheries play an important role in the management of salmon and steelhead populations in the Pacific Northwest. Nevertheless, the traditional practice of replacing natural populations with hatchery fish to mitigate for habitat loss and mortality resulting from hydropower dams is not consistent with contemporary conservation principles and scientific knowledge. Hatchery fish cannot replace lost habitat or the natural populations that rely on that habitat.

The HSRG concluded that hatchery programs should be viewed as tools that can be managed as part of a coordinated strategy to meet watershed or regional resource goals, in concert with actions affecting habitat, harvest rates, water allocation, and other factors that influence salmon and steelhead survival. The HSRG summary conclusions regarding areas where current hatchery and harvest practices need to be reformed through policy, management, research, and monitoring practices were as follows:

- Manage hatchery broodstocks to achieve proper genetic integration with, or segregation from, natural populations.
- Promote local adaptation of natural and hatchery populations.
- Minimize adverse ecological interactions between hatchery- and natural-origin fish.
- Minimize effects of hatchery facilities on the ecosystem.
- Maximize survival of hatchery fish.

The HSRG also developed three principles for hatchery management that are applicable to hatchery programs across Puget Sound, the Washington Coast, and the Columbia Basin: (1) develop clear, specific, and quantifiable harvest and conservation goals for natural and hatchery populations within an "all-H" context, (2) design and operate hatchery programs in a scientifically defensible manner, and (3) monitor, evaluate, and adaptively manage hatchery programs. The HSRG concluded that the more closely hatchery programs adhere to these principles, the greater the likelihood of their contribution to the managers' harvest and conservation goals.

Local recovery planners considered the HSRG's general and population-specific recommendations in developing hatchery actions for their recovery plans.

#### *1.5.5.5 State-Level Planning Processes*

**Native Fish Conservation Policy**

The Oregon Fish and Wildlife Commission adopted the Native Fish Conservation Policy (NFCP) in November 2002 to provide a basis for managing fisheries, habitat, hatcheries, predators, competitors, and pathogens in balance with sustainable production of naturally produced native fish. The three goals of the policy are to (1) prevent the serious depletion of native fish, (2) restore and maintain naturally produced fish in order to provide substantial ecological, economic and cultural benefits to the citizens of Oregon, and (3) foster and sustain opportunities for fisheries consistent with the conservation of naturally produced fish and responsible use of hatcheries. The NFCP is to be implemented and its goals achieved through the development of conservation plans for individual groups of populations, or species management units. The *Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead* (Oregon Department of Fish and Wildlife 2010) meets the requirements for NFCP conservation plans as well as those for an ESA recovery plan for salmon and steelhead.

**Oregon Plan for Salmon and Watersheds**

In 1997 Oregon's Governor and Legislature adopted the Oregon Plan for Salmon and Watersheds to begin state-led recovery efforts. The mission of the plan is to restore Oregon's native fish populations and the aquatic systems that support them to productive and sustainable levels that will provide substantial environmental, cultural,

and economic benefits. The plan has a strong focus on salmon, with actions designed to improve water quality and quantity and restore habitat.

Oregon is implementing the Oregon Plan for Salmon and Watersheds in a manner that is consistent with ESA recovery planning and other Oregon programs related to salmon. Watershed councils and soil and water conservation districts lead efforts in many subbasins, with support from landowners and other private citizens, recreational and commercial fishing interests, the timber industry, environmental groups, agriculture, utilities, businesses, tribes, and all levels of government. The Oregon Plan relies on volunteerism and stewardship, public education and awareness, scientific oversight, coordinated tribal and government efforts, and ongoing monitoring and adaptive management to achieve program success.

**Oregon Watershed Enhancement Board**

The Oregon Watershed Enhancement Board (OWEB) is a state agency that supports Oregon's efforts to improve water quality, strengthen ecosystems, and restore salmon runs. OWEB coordinates the Oregon Plan for Salmon and Watersheds' implementation of recovery plans for both state and federally listed species, including ESA-listed salmonids in the Columbia River and Upper Willamette basins. OWEB administers a grant program funded from Oregon Lottery proceeds and salmon license plate sales. The program funds the cooperative conservation work of a wide variety of participants, with up to 70 percent of the grant funding apportioned to on-the-ground restoration projects. OWEB also administers three other salmon-related programs: (1) the federal Pacific Coastal Salmon Recovery Funds (PCSRF) for the state, for projects that measurably contribute to the recovery of ESA-listed salmon and steelhead, (2) the OWEB Small Grant Program for local watershed restoration, and (3) the Conservation Reserve Enhancement Program (CREP), a voluntary land retirement program that helps agricultural landowners establish riparian vegetation along streams.

**Washington Watershed Planning**

The state Watershed Management Act (Revised Code of Washington [RCW] 90.82) gives local communities the opportunity to plan for the future use of their water resources in consultation with state agencies. To facilitate this planning, the state has been divided into Water Resource Inventory Areas (WRIAs), seven of which are within the Lower Columbia recovery planning area.[17] The Lower Columbia Fish Recovery Board coordinates watershed planning in four of the seven lower Columbia WRIAs. Klickitat County coordinates watershed planning in the White Salmon WRIA. Watershed plans for these WRIAs will address issues associated with water quantity, water quality, stream flows, and habitat, including the current condition of fish habitat and measures to protect or enhance habitat to support salmon recovery efforts.

Water quantity and quality and stream flow studies and data collected by the watershed planning initiatives have been incorporated into the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB 2010a), and habitat data collected

[17] WRIA 24 is partially in the Lower Columbia River subdomain; WRIAs 25, 26, 27, 28, and 29 are wholly within the Lower Columbia River subdomain; WRIA 29 is split into 29A (Wind) and 29B (White Salmon).

through the recovery planning effort has been shared with the watershed planning effort. Policies, strategies, actions, and priorities associated with ESA recovery planning and water resource planning are being coordinated to ensure that they are compatible and complement each other.

**Washington Salmon Habitat Protection and Restoration**

The Washington Salmon Recovery Act (RCW 77.85) provides for the funding of habitat protection and restoration efforts, requires local and regional program organizations to identify and prioritize project needs, and directs the Washington Department of Fish and Wildlife to develop guidance for regional salmon recovery efforts.

The Salmon Recovery Funding Board (SRFB) coordinates the funding process on the statewide level. It establishes program policies and directions and grant requirements, screens project proposals, and awards grants. Lead entities coordinate the process on the local or regional level. They develop habitat protection and restoration strategies for their area and solicit, evaluate, rank, and propose projects to the SRFB. The Lower Columbia Fish Recovery Board serves as the lead entity for most of the lower Columbia subdomain. In this capacity, the LCFRB has developed and annually updated and expanded a lower Columbia habitat strategy that provides a basis for prioritizing proposed habitat projects. Development of the strategy has been merged with ESA recovery planning in Washington such that elements of the strategy became an integral part of the *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* (LCFRB 2010a) and thus this ESU-level recovery plan. Klickitat County serves as the lead entity for the White Salmon subbasin and has developed a strategy to guide prioritization of proposed habitat projects for that watershed.

## 1.6 Tribal Treaty and Trust Responsibilities

The salmon and steelhead that were once abundant in the watersheds of the lower Columbia Basin were crucial to Native Americans throughout the region. Pacific Northwest Indian tribes today retain strong spiritual and cultural ties to salmon and steelhead, based on thousands of years of use for tribal religious/cultural ceremonies, subsistence, and commerce. Many Northwest Indian tribes have treaties reserving their right to fish in usual and accustomed fishing places, including areas covered by this recovery plan. Additionally, four Washington coastal tribes have treaty rights to ocean salmon harvest that may include some Lower Columbia River salmon stocks. These Columbia Basin and Washington Coast treaty tribes are co-managers of salmon stocks and participate in management decisions, including those related to hatchery production and harvest. Some other tribes in the Columbia Basin, whose reservations were created by Executive Order, do not have treaty reserved rights but do have a trust relationship with the federal government and an interest in salmon and steelhead management, including harvest and hatchery production. Other Indian tribes, while not asserting treaty reserved rights, do fish for subsistence and ceremonial purposes in areas covered by this plan, in compliance with agreements with the state of Oregon.

The NMFS Regional Administrator, in testimony before the U.S. Senate Indian Affairs Committee (Lohn 2003), emphasized the importance of this co-manager relationship: "We have repeatedly stressed to the region's leaders, tribal and non-tribal, the

importance of our co-management and trust relationship to the tribes. NMFS enjoys a positive working relationship with our Pacific Northwest tribal partners. We view the relationship as crucial to the region's future success in recovery of listed salmon."

Native American treaty-reserved fishing rights in the Columbia basin are under the continuing jurisdiction of the U.S. District Court for the District of Oregon in the case *United States v. Oregon*, No. 68-513 (filed in 1968). In *U.S. v. Oregon*, the Court affirmed that certain treaties reserved for the tribes up to 50 percent of the harvestable surplus of fish destined to pass through their usual and accustomed fishing areas. The *U.S. v. Oregon* process affects the allocation of harvest among various fisheries and thus affects how fisheries are managed in the lower Columbia River; in addition, Lower Columbia River populations that spawn above Bonneville Dam are intercepted in tribal fisheries.

Restoring and sustaining a sufficient abundance of salmon and steelhead for harvest is an important requirement in fulfilling tribal fishing aspirations. It is NMFS' policy to promote restoration of salmon and steelhead runs sufficient for tribal harvest. This policy is described in a July 21, 1998, letter from Terry D. Garcia, Assistant Secretary for Oceans and Atmosphere, U.S. Department of Commerce, to Mr. Ted Strong, Executive Director of the Columbia River Inter-Tribal Fish Commission. This letter states that recovery "must achieve two goals: (1) the recovery and delisting of salmonids listed under the provisions of the ESA, and (2) the restoration of salmonid populations over time, to a level to provide a sustainable harvest sufficient to allow for the meaningful exercise of tribal fishing rights." Thus it is appropriate for recovery plans to acknowledge tribal harvest goals. Where tribal harvest goals can only be met through hatchery production, recovery plans will identify strategies and actions to ensure that the hatchery production is consistent with recovery of naturally spawning populations.

# 2. Defining Viability for Salmon and Steelhead

This chapter presents biological background information that will aid the reader in understanding the limiting factor and threats analyses, recovery criteria and goals, and recovery strategies that are part of this ESU-level recovery plan. Specifically, the chapter describes basic concepts in salmonid biology (i.e., biological structure, population viability, and critical habitat), presents biological criteria the WLC TRT developed for assessing the viability of Lower Columbia River salmon and steelhead, and briefly summarizes methods and benchmarks the WLC TRT recommends for evaluating individual population status. (Chapter 5 provides additional details on methods.) Recovery goals in the management unit plans and NMFS' criteria for delisting the Lower Columbia River species are both based on this work of the WLC TRT. (See Chapter 3 for recovery goals and delisting criteria.)

## 2.1 ESU/DPS Biological Structure

Salmonid species' homing propensity (their tendency to return to the locations where they originated) creates unique patterns of genetic variation and connectivity among spawning areas across the landscape. Diverse genetic, life history, and morphological characteristics have evolved in salmon and steelhead over generations, creating runs adapted to diverse environments. It is this variation that gives a salmonid species as a whole the resilience to persist over time.

Historically, a salmon ESU or steelhead DPS typically contained multiple populations connected by some small degree of genetic exchange that reflected the geography of the river basins in which they spawned. Thus, the overall biological structure of the ESU or DPS is hierarchical, and spawners in the same area of the same stream share more characteristics than those in the next stream over. Fish whose natal streams are separated by hundreds of miles generally have less genetic similarity. The ESU or DPS is essentially a metapopulation defined as a group of populations connected by limited exchange of migrants. Recovery planning efforts focus on this biologically based hierarchy, which reflects the degree of connectivity between the fish at each geographic and conceptual level.

McElhany et al. (2000) identified two levels in this hierarchy for recovery planning purposes: the evolutionarily significant unit and the independent population. The WLC TRT identified an additional level between the population and ESU/DPS levels: the stratum (McElhany et al. 2003). Strata are analogous to major population groups (MPGs) as defined by the Interior Columbia TRT and to geographic regions described by the Puget Sound TRT.

This recovery plan adopts the ESU/DPS, stratum, and population structure described below. NMFS and the WLC TRT identified the ESUs/DPS, strata, and populations of Lower Columbia River salmon and steelhead based on geography, migration rates, genetic attributes, life history patterns, phenotypic characteristics, population dynamics, and environmental and habitat characteristics (Myers et al. 2006), as well as an understanding of the characteristics of viable salmonid populations (McElhany et al. 2000).

### 2.1.1 Evolutionarily Significant Units and Distinct Population Segments

Two criteria define an ESU of salmon under NMFS' ESU policy: (1) it must be substantially reproductively isolated from other conspecific units, and (2) it must represent an important component of the evolutionary legacy of the species (Waples 1991).

Two similar but slightly different criteria define a DPS of steelhead under the joint NMFS-U.S. Fish and Wildlife Service DPS policy: (1) discreteness of the population segment in relation to the remainder of the species to which it belongs, and (2) significance of the population segment to the species to which it belongs.

An ESU or DPS can contain multiple populations that are connected by some degree of migration, and hence may have a broad geographic range across watersheds, river basins, and political jurisdictions.

### 2.1.2 Strata

Within an ESU or DPS, independent populations can be grouped into larger groups based on ecological zone and dominant life history strategy, expressed as run timing, meaning the time of year when salmon return to native freshwater systems. These major population groups, or strata, share similar genetic, geographic, and/or habitat characteristics. Strata are isolated from one another over a longer time scale than that defining the individual populations, but they retain a degree of connectivity greater than that between different ESUs or DPSs. Figure 2-1 shows the relationship between ESU/DPS, strata, and independent populations.

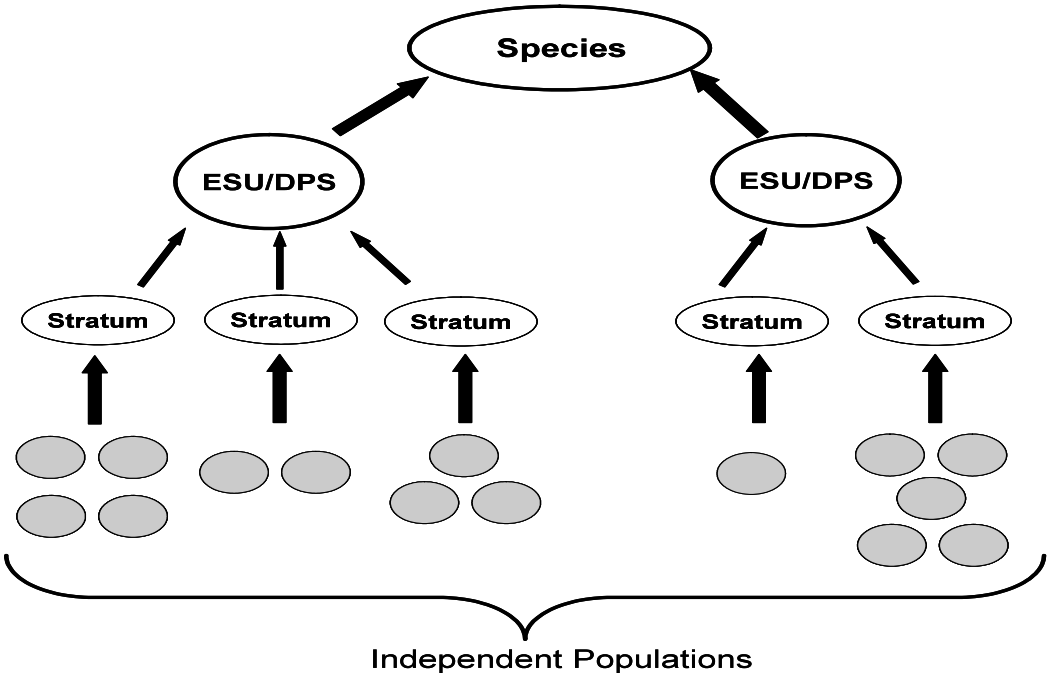


**Figure 2-1.** *Hierarchical Levels of Salmonid Species Structure for ESU/DPS Recovery Planning*
Source: ODFW 2010.

In the case of Lower Columbia River salmon and steelhead, strata are defined by a combination of ecological zone—Coast, Cascade, or Gorge—and dominant life history strategy, such as spring, fall, or late fall run timing. For example, Cascade fall Chinook and Cascade spring Chinook are separate strata. (See Tables 6-2, 7-2, 8-1, and 9-2 for the historical populations and strata for the salmon ESUs and steelhead DPS covered by this recovery plan.)

### 2.1.3 Independent Populations

McElhany et al. (2000) defined an independent population as follows:

> "… a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season. For our purposes, not interbreeding to a 'substantial degree' means that two groups are considered to be independent populations if they are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year time frame."

It is seldom possible to obtain exact measures of the degree of interbreeding between groups of fish. Therefore, the WLC TRT used several kinds of information to build up an understanding of population boundaries: geography, migration rates, genetic attributes, patterns of life history and phenotype (visible characteristics), abundance data, and environment (Myers et al. 2006). According to WLC TRT definitions, a population cannot be larger than a stratum or an ESU or DPS.

## 2.2 Viable Salmonid Populations

Viability is a key concept within the context of the Endangered Species Act. A viable salmonid ESU or DPS is naturally self-sustaining over the long term. A viable salmonid population has a negligible risk of extinction over a 100-year time frame (McElhany et al. 2000). McElhany et al. (2000) describe viable salmonid populations (VSPs) in terms of four parameters: abundance, population productivity or growth rate, population spatial structure, and life history and genetic diversity. Although these parameters sometimes are analyzed discretely, they are closely associated, such that improvements in one parameter typically cause or are related to improvements in another. For example, productivity improvements might depend on increased diversity or habitat quality and be accompanied by increased abundance and distribution.

### 2.2.1 Abundance and Productivity

Abundance refers to the number of spawners (adults on the spawning ground), averaged over a time period sufficient to account for year-to-year fluctuations that are due to natural environmental variation. The productivity of a population (the average number of surviving offspring per parent) is a measure of the population's ability to sustain itself. Productivity can be measured as spawner-to-spawner ratios (returns per

spawner or recruits per spawner, meaning adult progeny to parent), annual population growth rate, or trends in abundance. Population-specific estimates of abundance and productivity are derived from time series of annual estimates, which typically are subject to a high degree of annual variability and sampling-induced uncertainties.

Abundance and productivity are linked. Populations with low productivity can still persist if they are sufficiently large, and small populations can persist if they are sufficiently productive. A viable salmonid population needs sufficient abundance to maintain genetic health and to respond to normal environmental variation, and sufficient productivity to enable the population to quickly rebound from periods of poor ocean conditions or freshwater perturbations.

The VSP guidelines for abundance recommend that a viable population should (1) be large enough to have a high probability of surviving environmental variation observed in the past and expected in the future, (2) be resilient to environmental and anthropogenic disturbances, (3) maintain genetic diversity, and (4) provide ecosystem functions (McElhany et al. 2000). Factors suggesting that a population is at a critically low size include decreased reproductive success because individuals cannot efficiently find mates, fixation of harmful genetic mutations or reduced fitness as a result of inbreeding, and random demographic effects, such as if the variation in individual reproduction becomes important.

Productivity guidelines for viability are reached when a population's productivity is such that abundance can be maintained above the viable level, viability is independent of hatchery subsidy, viability is maintained even during sequences of poor environmental conditions, declines in abundance are not sustained, life history traits are not in flux, and conclusions about a population's productivity are independent of uncertainty in parameter estimates (McElhany 2000).

Viability analyses of Lower Columbia River salmon and steelhead suggest that, in general, populations of at least 500 fish are needed to ensure that critically low numbers do not result from normal variations in environmental conditions (McElhany et al. 2003). However, this number does not reflect actual minimum viable population sizes for the purposes of recovery planning. The abundance and productivity needed for recovery varies from one population to the next because of differences in habitat quantity, habitat quality, fish distribution, juvenile production, spatial structure, and life history and genetic diversity. The recovery goals in Chapter 3 reflect these variations.

### 2.2.2 Spatial Structure and Diversity

Considerations of spatial structure and diversity are combined in the evaluation of a salmonid population's status because they often overlap. A population's spatial structure is made up of both the geographic distribution of individuals in the population and the processes that generate that distribution (McElhany et al. 2000). Spatial structure refers to the amount of habitat available, the organization and connectivity of habitat patches, and the relatedness and exchange rates of adjacent populations. Spatial structure influences the viability of salmon and steelhead because populations with restricted distribution and few spawning areas are at a higher risk of extinction as a result of catastrophic environmental events, such as a landslide, than are populations

with more widespread and complex spatial structures. A population with a complex spatial structure, including multiple spawning areas, experiences more natural exchange of gene flow and life history characteristics. (However, excessive exchange of migrants above historical levels can impede the process of local adaptation.)

Diversity refers to the distribution of life history, behavioral, and physiological traits within and among populations. Some traits are completely genetically based, while others, including nearly all morphological, behavioral, and life history traits, vary as a result of a combination of genetic and environmental factors (McElhany et al. 2000).

Like spatial structure, population-level diversity is important for long-term persistence of salmon and steelhead. Populations exhibiting greater diversity are generally more resilient to short-term and long-term environmental changes. Phenotypic diversity, which includes variation in morphology and life history traits, allows more diverse populations to use a wider array of environments, and protects populations against short-term temporal and spatial environmental changes. Underlying genetic diversity provides the ability to survive long-term environmental changes.

Because neither the precise role that diversity plays in salmonid population viability nor the relationship of spatial processes to viability is completely understood, the management unit plans and this ESU-level recovery plan adopt the principle from McElhany et al. (2000) that historical spatial structure and diversity should be taken as a "default benchmark," on the assumption that historical, natural populations did survive many environmental changes and therefore must have had adequate spatial structure and diversity.

McElhany et al. (2000) also offers spatial structure and diversity guidelines for viable salmonid populations. Spatial structure guidelines are reached when the number of habitat patches is stable or increasing, stray rates are stable, marginally suitable habitat patches are preserved, refuge source populations are preserved, and uncertainty is taken into account. Diversity guidelines are reached when variation in life history, morphological, and genetic traits is maintained; natural dispersal processes are maintained; ecological variation is maintained; and the effects of uncertainty are considered.

For all four of the viable salmonid population parameters, the guidelines recommend that population-specific status evaluations, goals, and criteria take into account the level of scientific uncertainty about how an individual parameter relates to a population's viability (McElhany 2000).

## 2.3 Critical Habitat

The ESA requires the federal government to designate critical habitat for any species it lists under the ESA, with critical habitat defined as occupied areas that contain physical or biological features that are essential for the conservation of the species and that may require special management or protection, and unoccupied areas that are essential for conservation. Critical habitat designations must be based on the best scientific information available, in an open public process, within specific time frames. The

designations are one factor to consider during the identification and prioritization of recovery actions in recovery plans.

A critical habitat designation applies only when federal funding, permits, or projects are involved. Under section 7 of the ESA, all federal agencies must ensure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of a listed species, or destroy or adversely modify its designated critical habitat. Before critical habitat is designated, careful consideration must be given to its economic impacts, impacts on national security, and other relevant impacts. The Secretary of Commerce may exclude an area from critical habitat if the benefits of exclusion outweigh the benefits of designation, unless excluding the area will result in the extinction of the species concerned.

In determining which areas should be critical habitat, NMFS identified the geographic areas occupied by the species and the physical or biological features essential for the conservation of the species. For all salmon ESUs and steelhead DPSs this includes sites and habitat components that support one or more life stages; examples include (1) freshwater spawning sites, (2) freshwater rearing sites, (3) freshwater migration corridors, and (4) estuarine areas. NMFS also identified features associated with these types of sites that play an essential role in maintaining habitat health. These features also describe the habitat factors associated with viability for all ESUs and DPSs (although the specific habitat requirements for each ESU and DPS differ by life history type and life stage).

On September 2, 2005, NMFS published a final rule (70 *Federal Register* 52630) to designate critical habitat for 13 ESUs and DPSs of ESA-listed salmon and steelhead. Lower Columbia River Chinook, steelhead, and chum were included in this rule, but critical habitat for Lower Columbia River coho has not yet been designated. Critical Habitat Assessment Review Teams rated the conservation value of all watersheds that supported populations of the listed species and, depending on the importance of the watersheds to salmonid survival, assigned ratings of high, medium, or low. These ratings were used in determining the final critical habitat designations.

The final designations focus on certain physical and biological elements that support one or more salmonid life stages (spawning, rearing, migration, and foraging) and that are essential to the conservation of the species. The designations balanced ratings of the areas that provide the greatest biological benefits for listed salmon and steelhead with economic and other costs.

Maps of the critical habitat areas are available at http://www.nwr.noaa.gov/Salmon-Habitat/Critical-Habitat/CH-Maps.cfm and in the Federal Register notice, which also contains legal descriptions of the critical habitat areas.

NMFS recognizes that salmon habitat is dynamic and that current understanding of areas important for conservation will likely change as recovery planning sheds light on areas that can and should be protected and restored. NMFS will update the critical habitat designations as needed based on information developed during recovery plan implementation.

## 2.4 WLC TRT Biological Viability Criteria

The WLC TRT developed biological viability criteria that it recommends be used to assess long-term extinction risk at the ESU, stratum, and population level. Based on best available science, these criteria consist of a combination of general statements and metrics that characterize viability; the WLC TRT also suggested methods of applying the criteria to assess the probability that a population, stratum, or ESU will persist. As described in Chapter 3, the biological viability criteria summarized below served as an important foundation from which the management unit planners decided on recovery goals and NMFS developed delisting criteria for Lower Columbia River salmon and steelhead ESUs.

### 2.4.1 Background

NMFS asked the WLC TRT to develop biological viability criteria for use as the basis of recovery goals and delisting criteria. Biological viability criteria describe ESU or DPS characteristics associated with a low risk of extinction for the foreseeable future and are defined at the ESU/DPS, stratum, and population levels. (A stratum is a group of independent populations that share similar environments, life-history characteristics, and geographic proximity.) The status of a salmon ESU or steelhead DPS as a whole is evaluated by considering the status of each of its strata; the status of a stratum, in turn, is determined by considering the status of each of its component populations.

At the ESU or DPS level, viability criteria inform the questions of how many and which populations need to be viable (i.e., at a low risk of extinction) and what the appropriate risk levels are for other populations so that the ESU or DPS as a whole has a low risk of extinction. For the Lower Columbia River salmon ESUs and steelhead DPS, biological viability criteria are based on guidelines developed by NMFS' Northwest Fisheries Science Center and published as a NMFS technical memorandum, *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). The guidelines in McElhany et al. (2000) are intended to aid in the following:

1. Management of risks to the ESU or DPS from catastrophic events. Having multiple, geographically dispersed populations in an ESU or DPS reduces the risk of extinction from a single catastrophic event.

2. Maintenance of long-term demographic processes. Having multiple populations in an ESU or DPS—some in proximity and some dispersed—allows natural demographic processes to occur, such as population-level extinction and recolonization.

3. Maintenance of long-term evolutionary potential. Having multiple populations distributed across the geography of the ESU or DPS and representing diverse life histories and phenotypes allows for the genetic processes characteristic of long-term evolution.

At the stratum level, the WLC TRT developed criteria to guide decisions about which populations to target for various levels of viability. At the population level, the TRT developed criteria that describe viable salmonid populations (VSPs) in terms of the

parameters of abundance, productivity, spatial distribution, and diversity, according to guidelines in McElhany et al. (2000). (See Section 2.5.5 of this recovery plan for the VSP guidelines.)

The TRT's biological viability criteria take the form of general statements that characterize viability, metrics that describe viable populations and strata, methodologies for evaluating whether a population or stratum is viable, and, if not, what its current extinction risk (or persistence probability) is. This chapter presents the WLC TRT's biological viability criteria and their recommended methods and metrics for evaluating population status.

### 2.4.2 Viability Criteria Technical Reports

The WLC TRT outlined its viability criteria for Lower Columbia River salmon and steelhead populations, strata, and ESUs in a series of technical reports. The *Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids* (McElhany et al. 2003) presents the WLC TRT's initial recommendations regarding ESU-, stratum-, and population-level viability criteria. For population-level criteria, this report considered five population-level attributes: (1) adult abundance and productivity (combined into a single attribute because abundance and productivity are so interlinked in their effect on extinction risk), (2) juvenile outmigrant growth rate, (3) spatial structure, (4) habitat, and (5) diversity. The 2003 interim report also introduced general principles and approaches for evaluating current population status and suggested a qualitative scoring system based on the five population attributes.[1]

In 2006 the WLC TRT produced *Revised Viability Criteria for Salmon and Steelhead in the Willamette and Lower Columbia Basins* (McElhany et al. 2006). The revised criteria relied on three population-level attributes instead of five: (1) abundance and productivity (still combined into a single attribute), (2) spatial structure, and (3) diversity. (Juvenile outmigrant productivity was incorporated into abundance and productivity, and habitat attributes were addressed as part of the discussion of listing factors criteria [McElhany et al. 2006]). The revised viability criteria also recommended the use of viability curves and minimum abundance thresholds to evaluate abundance and productivity—rather than the population change criteria approach suggested in McElhany et al. (2003)—and provided initial viability curves and benchmarks for the Lower Columbia River ESUs.[2]

Additional work to refine approaches for evaluating population status was captured in *Viability Status of Oregon Salmon and Steelhead Populations in the Willamette and Lower Columbia Basins* (McElhany et al. 2007). This document is not a WLC TRT product, as the WLC TRT had dissolved in 2006 after completing the revised viability criteria in McElhany et al. (2006). Instead, *Viability Status of Oregon Salmon and Steelhead Populations*

[1] The 2003 interim report was supplemented in 2004 by the *Status Evaluation of Salmon and Steelhead Populations in the Willamette and Lower Columbia River Basins* (McElhany et al. 2004), which applied the methodology described in McElhany et al. (2003) to Lower Columbia River salmon and steelhead populations and some Upper Willamette populations.

[2] The 2006 report also discussed methods for evaluating population status in more depth than previous reports; refined analyses, metrics, and benchmarks; and applied the spatial structure methodology to Oregon LCR coho as a demonstration and test case, using newly available habitat accessibility maps published in 2005 (Maher et al. 2005). For more detail on the TRT's population status assessment methodology, see Section 2.6 of this recovery plan.

*in the Willamette and Lower Columbia Basins* (McElhany et al. 2007) was a collaborative effort of NMFS Northwest Fisheries Science Center staff, ODFW staff, and a private consultant working for the Lower Columbia Fish Recovery Board to refine population status assessments for the Oregon and Washington management unit plans. The document is described here because it made valuable contributions to methods for population status assessment.

McElhany et al. (2007) provides modified minimum abundance thresholds and viability curves for the Lower Columbia River ESUs. It also provides additional detail on how to evaluate the diversity attribute. Lastly, the 2007 document applies the WLC TRT recommendations for evaluating population status to Oregon populations of Lower Columbia River salmon and steelhead. Especially for spatial structure, the methods and approaches are similar to those in the 2006 report; where they differ, the methods described and demonstrated in *Viability Status of Oregon Salmon and Steelhead Populations in the Willamette and Lower Columbia Basins* (McElhany et al. 2007) supersede those in the 2006 report and earlier WLC TRT documents.

The WLC TRT's viability criteria are summarized below.

### 2.4.3 TRT ESU-Level Viability Criteria

#### *2.4.3.1 Defining ESU-Level Viability*

As described in Section 2.1, each Lower Columbia River salmon and steelhead stratum is defined by a combination of ecological zone (Coast, Cascade, or Gorge) and dominant life history strategy, expressed as run timing (fall, winter, etc.). The WLC TRT defined a viable Lower Columbia River ESU or DPS in terms of the status of its component strata:

> In a viable ESU or DPS, "every stratum (life history and ecological zone combination) that historically existed should have a high probability of persistence" (McElhany et al. 2003 and 2006).

The strata represent major diversity units within the ESU or DPS. Given the correlation between diversity and species resilience, the persistence of every historical stratum provides a substantial buffer against the negative effects of environmental variation, catastrophic events, and loss of genetic variation. It is the TRT's view that the loss of any particular stratum within an ESU or DPS would significantly reduce the resilience of that ESU or DPS and significantly increase its risk of extinction.

#### *2.4.3.2 ESU-Level Recovery Strategy Guidelines*

The WLC TRT also suggested two guidelines for use in developing ESU-level recovery strategies:

- **Non-deterioration**: Until all ESU viability criteria have been achieved, no population should be allowed to deteriorate in its probability of persistence.

- **Safety factors:** High levels of recovery should be attempted in more populations than recommended for strata-level viability because not all attempts will be successful. (McElhany et al. 2003 and 2006)

These guidelines emphasize the uncertainties inherent in the recovery process and build in safety factors to increase the likelihood of achieving viability goals. The WLC TRT illustrated the benefit of targeting more than the minimum number of populations for high levels of recovery by calculating that the chances of recovering at least three populations within an ESU go from 51 percent to 95 percent if the number of populations in which recovery is attempted goes from three to six, assuming that the probability of successful recovery for any given population is 80 percent (McElhany et al. 2003).

### 2.4.4 TRT Stratum-Level Viability Criteria

If a viable ESU or DPS is one in which every stratum that existed historically has a high probability of persistence, what constitutes a high-persistence stratum? It is the WLC TRT's view that, although representative populations need to be preserved, not every historical population needs to be restored for a stratum to be highly persistent. The WLC TRT defined a high-persistence stratum in terms of two criteria, the first concerning the number of populations that need to be viable and the second concerning which populations need to be viable.

#### *2.4.4.1 Criterion 1: How Many Populations in the Stratum Should Be Viable?*

> **Criterion 1:** Individual populations within a stratum should have persistence probabilities consistent with a high probability of strata persistence (McElhany 2003 and 2006).

The WLC TRT further described this criterion in terms of an adequate persistence probability for each individual population, using a four-point scale. As shown in Table 2-1, 0 indicates a population that has a very low probability of persisting over a 100-year time frame and 4 indicates a population that has a very high probability of persisting.

**Table 2-1**
*Population Viability Categories, Corresponding to 100-Year Extinction Risk*

| Probability of Persistence* | Extinction Risk | Population Viability | Persistence Score |
|---|---|---|---|
| 0 – 40% | Extinct or very high risk of extinction (VH) | Very low (VL) | 0 |
| 40 – 75% | Relatively high risk of extinction (H) | Low (L) | 1 |
| 75 – 95% | Moderate risk of extinction (M) | Medium (M) | 2 |
| 95 – 99% | Low/negligible risk of extinction (L) | High (H) | 3 |
| > 99% | Very low risk of extinction (VL) | Very high (VH) | 4 |

* Probability of population persisting over a 100-year time frame.
Source: McElhany et al. (2006).

The extinction risk of the entire stratum is determined by averaging the viability scores for the individual populations that make up the stratum, with an average of 2.25 or higher indicating a stratum that has a high probability of persistence. Additionally, the WLC TRT recommended that a stratum have at least two populations with a viability score of 3 or higher for the stratum to be considered highly likely to persist. (Table 2-2 shows the stratum-level extinction risks associated with different averages of population risk.)

In other words, for a stratum to have a high probability of persistence, at least two populations must be at least 95 percent likely to persist over a 100-year time frame and the average viability of all the populations in the stratum must be 2.25 or higher. (This is roughly equivalent to requiring that at least 50 percent of the populations in a stratum be viable, but using the average population persistence score recognizes that population status is a continuum and not a simple dichotomy of viable or not viable.)

**Table 2-2**
*Stratum-Level Extinction Risk Associated with Population Risk*

| Probability of Stratum Persistence | Population Persistence |
|---|---|
| Low Persistence | Average score: < 2 |
| Moderate Persistence | Average score: 2 to < 2.25<br>At least two populations: 3 or higher |
| High Persistence | Average score: 2.25 or higher<br>At least two populations: 3 or higher |

Source: McElhany et al. (2003).

#### *2.4.4.2 Criterion 2: Which Populations in the Stratum Should Be Viable?*

The TRT presented a second stratum-level criterion that offers guidance on which populations need to be viable:

**Criterion 2:** Within a stratum, the populations restored/maintained at viable status or above should be selected to:

a. Allow for normative metapopulation processes, including the viability of "core" populations, which are defined as the historically most productive populations.

b. Allow for normative evolutionary processes, including the retention of the genetic diversity represented in relatively unmodified historical gene pools.

c. Minimize susceptibility to catastrophic events. (McElhany 2003 and 2006)

Thus, a stratum with a high probability of persistence should include "core" populations, meaning those that historically were the most productive; "genetic legacy" populations, which best represent historical genetic diversity; and populations dispersed in a way that protects against the effects of catastrophic events.

### 2.4.5 TRT Population-Level Viability Criteria

The status of an ESU and its component strata depend on the viability status of the individual populations that make up that stratum and the ESU. The WLC TRT developed criteria to describe a viable population, based on the population attributes of abundance, productivity, diversity, and spatial structure as described in McElhany et al. (2000). These attributes, also known as viable salmonid population (VSP) parameters, are important indicators of population extinction risk—or, conversely, a population's probability of persistence. Guidelines from McElhany et al. (2000) that describe viable populations in terms of the VSP attributes are described in Section 2.2 of this recovery plan and presented in Table 2-3.

The population-level viability criteria developed by the WLC TRT for Lower Columbia River salmon and steelhead can be summarized as follows:

- **Abundance/productivity:** A viable population demonstrates growth rates, productivity, and abundance that produce an acceptable probability of population persistence. In highly viable populations, average abundance is approximately equivalent to the estimated historical average and the population is either stable in size or growing.

- **Spatial structure:** A viable population has a spatial structure that supports the population at the desired productivity, abundance, and diversity levels through short-term environmental perturbations, longer-term environmental oscillations, and natural patterns of disturbance regimes.

- **Diversity:** A viable population has sufficient life-history and genetic diversity to sustain the population through short-term environmental perturbations and provide for long-term evolutionary processes.

Table 2-3 presents the WLC TRT's population-level viability criteria, along with its stratum- and ESU-level viability criteria and its ESU-level strategy guidelines. TRT-recommended metrics and methodologies for use in evaluating the current risk status of independent populations are presented in McElhany et al. 2006 and 2007 and explained

in more detail in Section 2.6 of this recovery plan. In general, the WLC TRT advises that the viability of a population be evaluated by first scoring each VSP parameter individually and then integrating the VSP scores into an overall viability score using a weighted average that emphasizes abundance/productivity, as described in McElhany et al. (2007). This approach is recommended because abundance and productivity are considered better predictors of extinction risk than are spatial structure and diversity (McElhany et al. 2007).

Although the population assessment techniques described in McElhany et al. (2007) represent the most current methods available during the recovery planning process for Lower Columbia River ESUs, it is expected that evaluation techniques will be refined as more data become available and scientific understanding increases.

**Table 2-3**
*Viability Criteria and Guidelines from the Willamette-Lower Columbia Technical Recovery Team*

**ESU-Level Viability Criteria**

1. Every stratum (life history and ecological zone combination) that historically existed should have a high probability of persistence. For a stratum to have a high probability of persistence, at least two populations must be at least 95 percent likely to persist over a 100-year time frame and the average viability of all populations in the stratum must be 2.25 or higher, using the scoring system presented in McElhany et al. 2003. (This is roughly equivalent to requiring that at least 50 percent of the populations in a stratum be viable, but using the average population persistence score recognizes that population status is a continuum and not a simple dichotomy of viable or not viable.)

**ESU-Level Strategy Guidelines**

1. Until all ESU viability criteria have been achieved, no population should be allowed to deteriorate in its probability of persistence.
2. High levels of recovery should be attempted in more populations than identified in the strata viability criteria because not all attempts will be successful.

**Stratum-Level Viability Criteria**

1. Individual populations within a stratum should have persistence probabilities consistent with a high probability of stratum persistence.
2. Within a stratum, the populations restored/maintained at viable status or above should be selected to:
   a. Allow for normative meta-population processes, including eth viability of "core" populations, which are defined as the historically most productive populations.
   b. Allow for normative evolutionary processes, including the retention of the genetic diversity represented in relatively unmodified historical gene pools.
   c. Minimize susceptibility to catastrophic events.

**Population-Level Viability Criteria**

**Abundance and Productivity**

**Recommendation 1**: In general, viable populations should demonstrate a combination of population growth rate, productivity, and abundance that produces an acceptable probability of population persistence. Various approaches for evaluating population productivity and abundance combinations may be acceptable but must meet reasonable standards of statistical rigor.

**Recommendation 2:** A population with a non-negative growth rate and an average abundance approximately equivalent to estimated historical average abundance should be considered to be in the highest persistence category. The estimate of historical abundance should be credible, the estimate of current abundance should be averaged over several generations, and the growth rate should be estimated with an adequate level of statistical confidence. This criterion takes precedence over Recommendation 1.

**Within-Population Diversity**

Sufficient life-history diversity must exist to sustain a population through short-term environmental perturbations and to provide for long-term evolutionary processes. The metrics and benchmarks for evaluating the diversity of a population should be evaluated over multiple generations and should include:

a. Substantial proportion of the diversity of a life-history trait(s) that existed historically
b. Gene flow and genetic diversity should be similar to historical (natural) levels and origins
c. Successful utilization of habitats throughout the range
d. Resilience and adaptation to environmental fluctuations

**Within-Population Spatial Structure**

The spatial structure of a population must support the population at the desired productivity, abundance, and diversity levels through short-term environmental perturbations, longer-term environmental oscillations, and natural patterns of disturbance regimes. The metrics and benchmarks for evaluating the adequacy of a population's spatial structure should specifically address:

a. Quantity: Spatial structure should be large enough to support growth and abundance, and diversity criteria.
b. Quality: Underlying habitat spatial structure should be within specified habitat quality limits for life-history activities (spawning, rearing, migration, or a combination) taking place within the patches.
c. Connectivity: Spatial structure should have permanent or appropriate seasonal connectivity to allow adequate migration between spawning, rearing, and migration patches.
d. Dynamics: The spatial structure should not deteriorate in its ability to support the population. The processes creating spatial structure are dynamic, so structure will be created and destroyed, but the rate of flux should not exceed the rate of creation over time.
e. Catastrophic Risk: The spatial structure should be geographically distributed in such a way as to minimize the probability of a significant portion of the structure being lost because of a single catastrophic event, either anthropogenic or natural.

Source: McElhany et al. (2003).

### 2.4.6 Population Size

All else being equal, a small population is at greater risk of extinction than a large population because of the populations' responses to environmental variability and other processes. Very small populations (in the range of a few hundred fish or fewer) are subject to elevated risks from catastrophic events, random fluctuations in individual reproductive success (i.e., demographic stochasticity), genetic inbreeding, failure to find mates, and other effects. Populations at such small sizes are said to be below a quasi-extinction threshold (QET) or critical risk threshold (CRT).[3] The WLC TRT documents and McElhany et al. (2007) provide estimated CRT values for Lower Columbia River salmon and steelhead populations.

The CRT values vary by species and historical watershed size. Among species, different life histories suggest different demographic and other risks. Watershed size is a factor because some processes, such as finding a mate, depend on the density of fish rather than the absolute number of fish.

At abundances above the CRT but still relatively small, populations are at elevated risk because random fluctuations may drive them below the CRT. For example, a population with 200 fish that lost half its members because of environmental fluctuations would have 100 fish and might be below the CRT. A population with 2,000 fish that lost half its members would still have 1,000 fish, which is likely to be above any CRT. The WLC TRT referred to the abundance at which a population was substantially vulnerable to elevated extinction risk because of environmental fluctuation as a minimum abundance threshold (MAT). The most recent MAT values for Lower Columbia River salmon and steelhead populations are in McElhany et al. (2007). The MAT values differ by species

[3] McElhany et al. (2000) and the WLC TRT (McElhany et al. 2003 and 2006) used the term quasi-extinction threshold. McElhany et al. (2007) adopted the term critical risk threshold.

and historical watershed size because CRT values differ based on these same attributes and because responses to environmental fluctuations vary by species.

## 2.5 WLC TRT Approach to Assessing Population Status

The WLC TRT provided guidelines, recommended methodologies, and suggested benchmarks for evaluating the status of Lower Columbia River salmon and steelhead populations in two technical reports: the *Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids* (McElhany et al. 2003) and *Revised Viability Criteria for Salmon and Steelhead in the Willamette and Lower Columbia Basins* (McElhany et al. 2006). Refinements in methodology were captured in *Viability Status of Oregon Salmon and Steelhead Populations in the Willamette and Lower Columbia Basins* (McElhany et al. 2007), which was prepared by the WLC TRT chair, other NMFS Northwest Fisheries Science Center staff, ODFW staff, and a consultant working for the Lower Columbia Fish Recovery Board.

The WLC TRT initially applied its techniques for scoring population status in a report completed in 2004 (McElhany et al. 2004). In 2006, the TRT applied revisions in its scoring methods to Oregon coho populations (McElhany et al. 2006). In 2007, the TRT chair, working with other Northwest Fisheries Science Center staff and technical recovery planning staff in Oregon and Washington, refined the TRT's approach and applied it to all Oregon salmon and steelhead populations (see McElhany et al. 2007).

The methodologies that the WLC TRT recommended for assessing population status are based on evaluation of the population parameters of abundance, productivity, spatial structure, and diversity, consistent with guidelines in the NOAA technical memorandum *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). In general, the WLC TRT recommended that the status of a population be determined by first evaluating each population attribute separately and assigning it a numerical value, on a 0-to-4 scale, and then integrating those values to yield a score, also on a 0-to-4 scale, that reflects the overall status of that population (see Table 2-4).

As shown in Table 2-4, a score of zero includes a relatively broad range of persistence probabilities (i.e., 0 to 40 percent). The WLC TRT documents characterized this as either "very high risk" or "extirpated or nearly so."[4] It often is difficult to distinguish a truly extirpated population from one that is at significant short-term risk but not entirely extirpated, and the WLC TRT's 0-to-4 scale does not make this distinction. In discussions of population status in this document, we use the terms "very high risk" or "extirpated or nearly so" unless a population has been completely blocked from access to historical habitat and/or is assumed to have no remnants either in a hatchery program or in the

[4] The term "extirpated" is preferred to the term "extinct" when describing a population because extirpation tends to refer to a small unit (e.g., a population), whereas extinction usually refers to a global phenomenon (e.g., an entire ESU). Extirpation also suggests a possibility for recolonization, whereas global extinction does not. Despite the preference for the term extirpation over extinction when referring to populations, the term extinction is used throughout older WLC TRT documents and the management unit plans.

wild. In this latter case (e.g., White Salmon and Hood River spring Chinook salmon) we refer to the populations as extirpated.[5]

**Table 2-4**
*Population Scores and Corresponding Probability of Persistence (or Extinction)*

| Score* | Probability of Persistence** | Population Status | Probability of Extinction** | Extinction Risk |
|---|---|---|---|---|
| 0 | 0 – 40% | Very low (VL) | 60 – 100% | Extinct or at very high risk of extinction (VH) |
| 1 | 40 – 75% | Low (L) | 25 – 60% | Relatively high risk of extinction (H) |
| 2 | 75 – 95% | Medium (M) | 5 – 25% | Moderate risk of extinction (M) |
| 3 | 95 – 99% | High (H) | 1 – 5% | Low/negligible risk of extinction (L) |
| 4 | > 99% | Very high (VH) | < 1% | Very low risk of extinction (VL) |

* Population scores between whole numbers are rounded. For example, a score of 2.75 would be rounded up to 3; a score of 2.45 would be rounded down to 2.

** Probability over a 100-year time frame.

Source: McElhany et al. (2006).

In some cases, the WLC TRT suggested quantitative methods of evaluating a particular population parameter; when this was not possible because of limitations of data or analytical technique, the TRT suggested qualitative approaches (see Table 2-3). Even where the TRT did develop quantitative evaluation methods, data for use in evaluating the individual VSP attributes often are limited. For these reasons, the WLC TRT noted the necessity of applying professional judgment when assessing population status. (For more information on the WLC TRT's approach to evaluating and scoring the population attributes of abundance/productivity, spatial structure, and diversity, see McElhany et al. 2004, 2006, and 2007.)

The WLC TRT recommended that the abundance and productivity attributes be combined and receive a single attribute score, and that overall population status be determined by averaging the population attribute scores for abundance/productivity, diversity, and spatial structure, with abundance/productivity weighted twice as heavily as the other attributes because abundance and productivity are considered better predictors of extinction risk (i.e., total score = 2/3 A&P + 1/6 spatial + 1/6 diversity). Furthermore, the WLC TRT recommended that, if the abundance/productivity score is lower than the diversity or spatial structure score, the abundance/diversity score be used to characterize overall population status, instead of the weighted average method. This approach avoids what could be a misleadingly high characterization of overall status in cases where a risk factor is driving down a population's abundance and productivity but not affecting its diversity and spatial structure. (For additional guidance on how to integrate the population attribute scores for to yield a score that reflects overall population status, see McElhany et al. 2007, p. 8).

[5] A reintroduction program for spring Chinook salmon in the Hood subbasin is under way using out-of-ESU broodstock. Some natural production is occurring there. At this time, the origin of that natural production is unknown. For additional discussion of this reintroduction program, see Section 7.4.3.6.

The WLC TRT-recommended methods and benchmarks for evaluating population status reflect scientific understanding at the time they were developed. In NMFS' view, the WLC TRT's approach represents one of several possible ways of evaluating population status that are scientifically credible and that follow WLC TRT guidelines. The WLC TRT's approach itself is not static, as evidenced by the many refinements in technique described in the technical reports between 2000 and 2007. NMFS expects that techniques for assessing population status will continue to improve over time as scientific understanding increases, and that future status evaluations will not necessarily use the exact techniques demonstrated by the WLC TRT. As more data become available and scientific understanding increases, NMFS expects to work with its recovery planning partners to further refine techniques for assessing population status.

# 3. Recovery Goals and Delisting Criteria

This chapter provides an overview of the recovery goals in the management unit plans and the delisting criteria NMFS will use in future status reviews of the Lower Columbia River salmon ESUs and steelhead DPS to determine whether delisting is warranted. This overview is supplemented with additional detail at the species level in Chapters 6 through 9.

Management unit plans incorporate several types of recovery goals. These include biological goals that are intended to be consistent with delisting, as well as "broad sense" recovery goals that go beyond the requirements for delisting under the ESA to address other legislative mandates or social, economic, and ecological values. Broad sense recovery goals may have a biological component, or they may be expressed solely in terms of aspirations to provide these other values. The biological components of management unit plan recovery goals rely heavily on biological viability criteria developed by the TRTs.

The formal delisting criteria are determined by NMFS and must meet ESA requirements. The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 Code of Federal Regulations [CFR] 17.11 and 17.12). These criteria are of two kinds: biological viability criteria, which deal with population or demographic parameters, and threats criteria, which relate to the five listing factors detailed in the ESA (see Sections 1.1 and 3.2.2 of this plan). The threats criteria define the conditions under which the listing factors, or threats, can be considered to be addressed or mitigated. Together the biological viability and threats criteria make up the "objective, measurable criteria" required under section 4(f)(1)(B) for the delisting decision.

Delisting criteria may include both technical and policy considerations, such as acceptable risk levels at the population, stratum, and ESU/DPS scales. They are based on the best available scientific information (including the WLC TRT's biological viability criteria) and incorporate the most current understanding of the ESU or DPS and the threats it faces. As this recovery plan is implemented, additional information may become available that improves our understanding of the status of populations and ESUs/DPSs, how best to evaluate population and ESU/DPS status, threats and how to evaluate their impacts on population and ESU/DPS status, or the extent to which threats have been abated. If appropriate, NMFS will review and revise delisting criteria in the future based on this new information.

NMFS has ultimate responsibility for final recovery plans and delisting decisions and must take into account all relevant information, including, but not limited to, biological and policy considerations developed during the recovery planning process.

## 3.1 Management Unit Plan Recovery Goals

Each management unit plan includes broad, conceptual statements of purpose and objectives, as well as broad sense recovery goals and biological goals that local planners believe are consistent with delisting.[1] Goals are identified at the population level but also have been coordinated among management unit plans to produce stratum- and ESU-level recovery scenarios. These recovery scenarios and their corresponding population-level biological goals are an important linkage between the management unit plans and the NMFS delisting criteria.

### 3.1.1 Plan Purposes and Broad Sense Recovery Goals

#### *3.1.1.1 Washington Management Unit Recovery Plan*

The Washington management unit plan is an integrated, ecosystem-focused plan that is intended to serve planning needs associated with the Endangered Species Act, the Northwest Power and Conservation Council's fish and wildlife subbasin planning process, and state salmon recovery and watershed planning. For this reason, the Washington plan includes some species that are not addressed in this recovery plan, such as steelhead in the Coast ecozone, which are part of the Southwest Washington DPS and not listed under the ESA, and also bull trout, a freshwater trout species that is listed as threatened under the ESA and is under the jurisdiction of the U.S. Fish and Wildlife Service.

The Washington management unit plan's overall vision is twofold:

- To recover Washington Lower Columbia River salmon, steelhead, and bull trout to healthy, harvestable levels that will sustain productive recreational, commercial, and tribal fisheries through the restoration and protection of the ecosystems upon which they depend and the implementation of supportive hatchery and harvest practices

- To sustain and enhance the health of other native fish and wildlife species in the lower Columbia through the protection of the ecosystems upon which they depend, the control of non-native species, and the restoration of balanced predator/prey relationships (LCFRB 2010a p. 1-2)

The first part of this vision encompasses a goal of delisting Lower Columbia River salmon and steelhead as one component of achieving the overall vision.

Harvestability is a key aspect of the vision for recovery presented in the Washington management unit plan and represents what is considered a "broad sense" recovery goal. The plan defines a viable species as one that is no longer in danger of extinction or likely to become endangered in the foreseeable future and can therefore be removed from listing under the ESA. The plan defines a harvestable species as one that has achieved viability and has abundance sufficient to allow direct and sustainable recreational, commercial, and tribal harvest without jeopardizing the species' viability (LCFRB 2010a).

[1] Section 3.2 discusses NMFS' view of the management unit plans' recovery goals.

The Washington management unit plan also states that harvestability goals are reached when adult natural production exceeds recovery targets and fish can be directly harvested at levels that maintain spawning escapement at or above those targets (LCFRB 2010a). Harvest of listed fish that have not achieved their target status is typically limited to indirect harvest in mixed-stock fisheries targeted on strong wild runs or hatchery fish. Allowable levels of indirect harvest impacts are established through ESA regulatory processes (LCFRB 2010a).

#### *3.1.1.2 Oregon Lower Columbia Management Unit Recovery Plan*

Like the Washington management unit recovery plan, the Oregon Lower Columbia management unit recovery plan is designed to meet multiple needs. It serves as both a federal recovery plan under the U.S. Endangered Species Act and a state conservation plan under Oregon's Native Fish Conservation Policy. The document's overall purpose is to guide the implementation of actions needed to recover Lower Columbia River salmon and steelhead in Oregon (ODFW 2010). In addition, the plan addresses some species and populations that are not part of the Lower Columbia River ESUs or DPS, such as steelhead in the Coast ecozone (these are part of the Southwest Washington DPS and not listed under the ESA) and Clackamas River spring Chinook salmon (which are part of the Upper Willamette ESU).

Also like the Washington management unit recovery plan, the Oregon Lower Columbia management unit plan contains broad sense goals that encompass ESA delisting. The plan's goals are as follows:

- To achieve ESA delisting.

- To achieve broad sense recovery, defined as having Oregon populations of naturally produced salmon and steelhead sufficiently abundant, productive, and diverse (in terms of life histories and geographic distribution) that the ESU as a whole will be self-sustaining and will provide significant ecological, cultural, and economic benefits (ODFW 2010)

The second goal was developed to fulfill the mission of the Oregon Plan for Salmon and Watersheds to restore "Oregon's native fish populations and the aquatic systems that support them to productive and sustainable levels that will provide substantial environmental, cultural, and economic benefits" (ODFW 2010).

Oregon's broad sense goal is consistent with ESA delisting but is designed to achieve levels of performance that are more robust than those needed to remove ESUs/DPSs from ESA protection. The plan's vision is that ESA delisting goals would be achieved first, during an extended and stepwise process of achieving the broad sense recovery goal, which would be based on a combination of legislative mandates, cultural commitments, social values, and voluntary contributions (ODFW 2010).

Oregon broke down its broad sense recovery goal into two criteria:

- All Oregon LCR salmon and steelhead populations have a very low extinction risk and are highly viable over 100 years throughout their historical range. A very low

extinction risk means a less than 1 percent probability of extinction over a 100-year period, based on an integrated assessment of the population's abundance, productivity, spatial structure, and diversity.

- The majority of Lower Columbia salmon and steelhead populations are capable of contributing social, cultural, economic and aesthetic benefits on a regular and sustainable basis (ODFW 2010).

In working toward the broad sense recovery goal, the Oregon Lower Columbia plan focuses on the status of Oregon populations only; meeting the broad sense recovery criteria does not depend on the performance of populations in Washington.

#### *3.1.1.3 White Salmon Management Unit Recovery Plan*

The primary goal of the White Salmon management unit recovery plan is to restore White Salmon populations of the Lower Columbia River salmon ESUs to a status consistent with overall ESU delisting criteria. The White Salmon management unit plan incorporates a general broad sense recovery goal to achieve a status beyond ESA delisting that incorporates local and traditional uses of salmon, including those associated with rural and Native American values. Local recovery planners and plan implementers may choose to define additional broad sense goals for the White Salmon management unit recovery plan in the future (NMFS 2013).

### 3.1.2 Management Unit Plan Biological Recovery Goals

Recovery planners at the management unit level largely followed the guidelines of the WLC TRT in assessing the viability of salmon and steelhead populations, strata, and ESUs/DPS for the purposes of setting recovery goals. The plans adopted the WLC TRT's definitions of a viable ESU or DPS (i.e., every historical stratum having a high probability of persistence) and a viable stratum (at least two populations being highly likely to persist and the average population persistence score being 2.25 or higher). In addition, the management unit planners relied heavily on the WLC TRT's guidelines regarding abundance and productivity, spatial structure, and diversity in setting viability goals for individual populations. In some cases, however, their approaches differed somewhat from the TRT's and from each other. Detail on methodologies, including discussion of any differences, can be found in Chapter 5. Chapters 6 through 9 present population-specific goals, such as abundance and productivity targets.

### 3.1.3 Recovery Scenarios for ESU/DPS

Although the WLC TRT defined ESU- and stratum-level viability, it did not specify target viability levels for individual populations consistent with those definitions. Conceivably, the TRT's ESU-level viability criteria could be met through many different combinations of individual population status, with the "best" combination being a function of biological and ecological conditions on the ground and local community values and interests. Management unit recovery planners used the TRT's ESU-level viability criteria to guide decisions about which populations to target for which levels of persistence probability.

Through an iterative process, recovery planners for the Washington Lower Columbia, Oregon Lower Columbia, and White Salmon management units collaborated to reach agreement on a target status for each population. The target statuses within an ESU or DPS are referred to collectively as the "recovery scenario" for that ESU or DPS. Setting the target status for each population in an ESU or DPS (i.e., developing the recovery scenario) involved consideration of several factors:

- Productivity. Which populations are "core" populations that historically were the most highly productive?

- Genetic diversity. Which populations are "legacy" populations that represent important historical genetic diversity?

- Geographical location. Are the populations targeted for high persistence probabilities dispersed in a way that minimizes risk from catastrophic events?

- Feasibility. Which populations can be expected to make significant progress toward recovery because of existing programs, the absence of apparent impediments to recovery, and other management considerations?

The recovery scenarios for the salmon ESUs and steelhead DPS are presented in Table 3-1. The table shows the target status of each population and that population's expected level of contribution to ESU/DPS recovery, using the terminology of "primary" (P), "contributing" (C), and "stabilizing" (S), taken from the Oregon and Washington management unit plans. Primary populations are targeted for restoration to a high or very high probability of persistence. Many primary populations currently have a medium probability of persistence, and some are at low or very low but are targeted for high or very high persistence probability in order to achieve a high probability of stratum and ESU persistence. Contributing populations are those for which some restoration will be needed to achieve a stratum-wide average persistence probability of 2.25 or higher. Stabilizing populations are those that are targeted for maintenance at their baseline persistence probabilities, which are likely to be low or very low. A population might be designated as stabilizing if the feasibility of restoration is low and the uncertainty associated with restoration is high. Chapters 6 through 9 describe the target status of each population further in terms of the viability parameters of abundance and productivity, diversity, and spatial structure (see Tables 6-4, 7-4, 8-2, and 9-4).

**Table 3-1**

*Recovery Scenarios for LCR Chinook, Columbia River Chum, LCR Steelhead, and LCR Coho*

| | | Chinook | | | | | | Chum | | | | Steelhead | | | | Coho | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fall | | Late Fall | | Spring | | Fall | | Summer | | Winter[3] | | Summer | | | |
| | | Contribu-tion [1] | Target [2] | Contribu-tion | Target | Contribu-tion | Target | Contribu-tion | Target | Contribu-tion | Target | Contribu-tion | Target | Contribu-tion | Target | Contrib-ution | Target |
| COAST | Youngs Bay (OR) | S | L | -- | -- | -- | -- | S | VL | -- | -- | | | -- | -- | S | VL |
| | Grays/Chinook (WA) | C | M+ | -- | -- | -- | -- | P | VH | -- | -- | | | -- | -- | P | H |
| | Big Creek (OR) | C | L | -- | -- | -- | -- | S | VL | -- | -- | | | -- | -- | S | VL |
| | Eloch./Skam. (WA) | P | H | -- | -- | -- | -- | P | H | -- | -- | | | -- | -- | P | H |
| | Clatskanie (OR) | P | H | -- | -- | -- | -- | P | H | -- | -- | | | -- | -- | P | VH |
| | Mill/Aber./Ger. (WA) | P | H | -- | -- | -- | -- | P | H | -- | -- | | | -- | -- | C | M |
| | Scappoose (OR) | P | H | -- | -- | -- | -- | P | H | -- | -- | | | -- | -- | P | VH |
| CASCADE | Lower Cowlitz (WA) | C | M+ | -- | -- | -- | -- | C (Cowlitz) | M | C (Cowlitz) | M | C | M | -- | -- | P | H |
| | Coweeman (WA) | P | H+ | -- | -- | -- | -- | | | | | P | H | -- | -- | P | H |
| | SF Toutle (WA) | P (Toutle) | H+ | -- | -- | C (Toutle) | M | | | | | P | H+ | -- | -- | P | H |
| | NF Toutle (WA) | | | -- | -- | | | | | | | P | H | -- | -- | P | H |
| | Upper Cowlitz (WA) | S (Upper Cowlitz) | VL | -- | -- | P | H+ | | | | | P | H | -- | -- | P | H |
| | Cispus (WA) | | | -- | -- | P | H+ | -- | -- | -- | -- | P | H | -- | -- | P | H |
| | Tilton (WA) | | | -- | -- | S | VL | -- | -- | -- | -- | C | L | -- | -- | S | VL |
| | Kalama (WA) | C | M | -- | -- | C | L | C | M | -- | -- | P | H+ | P | H | C | L |
| | NF Lewis (WA) | P (Lewis) | H+ | P | VH | P | H | P (Lewis) | H | -- | -- | C | M | S | VL | C | L |
| | EF Lewis (WA) | | | -- | -- | -- | -- | | | -- | -- | P | H | P | H | P | H |
| | Salmon (WA) | S | VL | -- | -- | -- | -- | S | VL | -- | -- | S | VL | -- | -- | S | VL |
| | Clackamas (OR) | C | M | -- | -- | --[4] | | C | M | -- | -- | P | H[6] | -- | -- | P | VH |
| | Sandy (OR) | C | M | P | VH | P | H | P | H | -- | -- | P | VH | -- | -- | P | H |
| | Washougal (WA) | P | H+ | -- | -- | -- | -- | P | H+ | -- | -- | C | M | P | H | C | M+ |
| GORGE | Lower Gorge (WA/OR) | C[5] | M | -- | -- | -- | -- | P[5] | VH | -- | -- | P[5] | H | -- | -- | P[5] | H |
| | Upper Gorge (WA/OR) | C[5] | M | -- | -- | -- | -- | C[5] (Upper Gorge) | M | -- | -- | S[5] | L | P (Wind) | VH | P (U. Gorge/W. Salmon) | H |
| | White Salmon (WA) | C | M | -- | -- | C | L+ | | | -- | -- | -- | -- | -- | -- | | |
| | Hood (OR) | P | H[6] | -- | -- | P | VH | | | -- | -- | P | H | P | H[6] | P (U.Gorge/ Hood) | H[6] |

[1] Indicates contribution to recovery: P = primary, C = contributing, S = stabilizing; for description, see Section 3.1.3.

[2] VL = very low persistence probability , L = low persistence probability, M = moderate persistence probability , H = high persistence probability, VH = very high persistence probability.

[3] Winter steelhead of the Coast stratum are included in the Washington and Oregon management unit plans for state-level planning purposes, but they are not included in this table because they are part of the unlisted Southwest Washington DPS, not the listed Lower Columbia River DPS.

[4] Clackamas spring Chinook are part of the Upper Willamette spring Chinook ESU.

[5] Designation for shared population based on WA objectives, with support to be provided by OR portion of population, since WA has a larger proportion of the population area.

[6] The Oregon management unit plan (ODFW 2010) notes that achieving this target status is highly unlikely for various reasons (see pp. 176-77, 186, 195, 200 of ODFW 2010).

The scenarios in Table 3-1 meet the WLC TRT criteria for high probability of persistence at the stratum and ESU or DPS levels with the exceptions of the Gorge fall Chinook, Gorge spring Chinook, and Gorge chum strata. In each of these strata, only one population is targeted to achieve a high probability of persistence. Local recovery planners documented the basis for this divergence from the TRT's criteria.

In Washington, planners factored feasibility into target status designations. Thus for the Gorge fall Chinook, spring Chinook, and chum strata, Washington recovery planners set the target status at levels they believed were feasible, even though these levels were not consistent with the WLC TRT's criteria for high probability of stratum persistence (LCFRB 2010a). Washington planners noted that the likelihood of meeting TRT criteria was highly uncertain because the Bonneville Dam reservoir inundates historical spawning habitat for fall Chinook and chum salmon that spawn in tributaries above the dam, the dam creates passage impediments, there is uncertainty regarding the extent to which some populations functioned independently historically, and, in the case of White Salmon spring Chinook, the population has been extirpated. In contrast, Oregon recovery planners set target viability status at levels consistent with the WLC TRT's criteria. However, in the case of the Hood River populations and the Oregon portions of the shared Gorge populations, Oregon recovery planners noted a very low probability of meeting those goals, in part because there is little habitat currently available and because anthropogenic impacts are unlikely to change in the near future (ODFW 2010).

In addition, both the Washington and Oregon management unit planners raised questions regarding stratum and population delineations and the historical role of the Gorge populations (LCFRB 2010a, ODFW 2010). Questions included whether the populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum. While the Washington management unit plan simply raised issues of uncertainty in stratum delineations between the Cascade and Gorge strata and in Chinook and chum population delineations (LCFRB 2010a), the Oregon management unit plan discussed the issue in more depth (see Appendix B of ODFW 2010). For example, the Oregon management unit plan cites a NMFS GIS analysis (see Busch et al. 2011) that used an intrinsic habitat potential model to show that potential habitat for Gorge populations, based on existing geomorphic features, is very small, even in relatively large watersheds (ODFW 2010). This suggests that, even historically, many Gorge populations might not have been sufficiently sized to be reproductively isolated from other populations and to exhibit the productivity required to ensure long-term sustainability. For all three salmon ESUs and the steelhead DPS, the Oregon management unit plan recommends that the Gorge stratum's historical status and population structure be reevaluated and that recovery goals be revised if modifications are made (ODFW 2010).

Finally, for Gorge fall and spring Chinook and Gorge chum, management unit planners developed recovery scenarios that exceed the TRT criteria in the Cascade stratum as a way of mitigating for increased risk to the ESU as a result of not achieving the WLC TRT's stratum-level criteria in the Gorge.

## 3.2 NMFS Delisting Criteria

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Lower Columbia River Chinook ESU, Lower Columbia River steelhead DPS, Lower Columbia River coho ESU, or Columbia River chum ESU from the Federal List of Endangered and Threatened Wildlife and Plants, NMFS must determine that the ESU or DPS, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12; 50 CFR 223.102 and 224.101). The biological and threats criteria in this plan, taken together, meet this statutory requirement.

### 3.2.1 Biological Criteria

NMFS has considered the WLC TRT's viability criteria (McElhany et al. 2003 and 2006, summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios (summarized in Table 3-1) and population-level goals in the management unit plans, and the questions the management unit planners raised regarding the historical role of the Gorge strata.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of an ESU that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the management unit plan recovery scenarios (summarized in Table 3-1 of this recovery plan) and population-level abundance, productivity goals[2] (see Chapters 6 through 9) and has concluded that they also adequately describe the characteristics of an ESU that no longer needs the protections of the ESA.[3] NMFS endorses the recovery scenarios and population-level goals in the management unit plans (summarized here in Table 3-1 and Sections 6.3, 7.3, 8.3, and 9.3) as one of multiple possible scenarios consistent with delisting.

As noted above, the recovery scenarios in Table 3-1 are consistent with the WLC TRT's recommendations at the stratum and ESU or DPS level, except for the Gorge fall Chinook, Gorge spring Chinook, and Gorge chum strata. In those strata, the recovery scenarios target only one population to achieve a high probability of persistence. As a way of mitigating for increased risk in the Gorge strata, the recovery scenarios exceed

[2] NMFS also evaluated the goals for spatial structure and diversity in the Oregon management unit plan (ODFW 2010). Washington recovery planners assumed that productivity and abundance levels consistent with significant improvements in persistence probability could not be achieved without also addressing limitations in spatial structure and diversity. Thus, spatial structure and diversity improvements are implicit in the abundance and productivity targets in the Washington management unit plan (LCFRB 2010a).
[3] See Sections 6.7, 7.7, 8.7, and 9.7 for additional detail on biological criteria at the species level.

the WLC TRT criteria in the Cascade fall Chinook, Cascade spring Chinook, and Cascade chum strata.

In its revised viability criteria (McElhany et al. 2006), the WLC TRT noted the need for case-by-case evaluations of the continuum of ESU-level risk associated with some strata not meeting the TRT's persistence criteria. In commenting on the recovery scenarios presented in the interim Washington management unit plan[4]—and by extension the recovery scenarios in Table 3-1 of this plan—the WLC TRT stated that achieving the recovery scenarios would improve the status of the Gorge strata, even if the TRT's criteria for those strata were not met. The TRT also noted that targeting the Cascade strata for very high persistence (above the minimum TRT criteria) would help lower ESU extinction risk. In addition, the TRT noted that the Gorge and Cascade strata are relatively similar compared to the Cascade and Coast strata. Also significant in the TRT's view was that options for recovery of the Gorge strata would be preserved, in case future conditions or analyses were to require high stratum persistence for ESU viability (McElhany et al. 2006).

Based on the information provided by the WLC TRT and the management unit recovery planners, NMFS concludes that the recovery scenarios in Table 3-1 and the associated population-level abundance and productivity goals in Sections 6.3, 7.3, 8.3, and 9.3 represent one of multiple possible scenarios that would meet biological criteria for delisting.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and strata merits further examination. The extent to which compensation in the Cascade strata is ultimately considered necessary to achieve an acceptably low risk level at the ESU or DPS level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following biological criteria for the four listed ESUs and DPS addressed by this plan (NMFS has amended the WLC TRT's criteria for clarity and to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge strata):

- All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition.

- High probability of stratum persistence is defined as:

    a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

    b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum

[4] In February 2006, NMFS approved the December 2004 *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* as in interim regional recovery plan. The 2010 revised version of that plan (LCFRB 2010a) is incorporated into this ESU-level plan as Appendix B.

population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

- A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

The recovery scenarios in Table 3-1 are consistent with these biological criteria.

### 3.2.2 Threats Criteria

In addition to a species achieving a certain biological status to be considered for reclassification or delisting, the threats to a listed species must have been ameliorated so as not to limit attainment of its desired biological status. Section 4(a)(1) of the ESA organizes NMFS' consideration of threats into five factors:

A. The present or threatened destruction, modification, or curtailment of the species' habitat or range
B. Over-utilization for commercial, recreational, scientific, or educational purposes
C. Disease or predation
D. The inadequacy of existing regulatory mechanisms
E. Other natural or human-made factors affecting the species' continued existence

These factors may not all be equally important in securing the continuing recovery of a particular ESU, and each ESU faces a different set of threats. It also is possible that current perceived threats will become insignificant in the future as a result of changes in the natural environment or changes in the way threats affect the entire life cycle of salmon and steelhead.

NMFS will use the listing factor criteria below in determining whether an ESU or DPS has recovered to the point that it no longer requires the protections of the ESA:

A. The present or threatened destruction, modification, or curtailment of a species' habitat or range:
    1. Habitat-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.
        a. Recovery plan actions addressing habitat limiting factors have been substantially implemented, including related research, monitoring, and evaluation actions.
        b. The threat reduction targets for habitat outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met

or habitat impacts are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, and to track and periodically evaluate progress, specific metrics for assessing habitat conditions and action effectiveness will be needed.

c. Trends in overall habitat conditions, based on evaluation of the combined effect of factors, including, but not limited to, habitat access, hydrograph/water quantity, physical habitat quality and quantity, and water temperature and other water quality parameters, are stable or improving.

d. Functioning habitat areas, including those expected to be less vulnerable to impacts from climate change, have been protected. Other actions to support adaptation to climate change impacts have been implemented.

2. Hydropower and/or flood control dam-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations, as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.

    a. Recovery plan actions addressing hydropower limiting factors have been substantially implemented, including related research, monitoring, and evaluation actions.

    b. FERC Settlement Agreements and relevant actions from the applicable FCRPS Biological Opinion have been substantially implemented.

    c. The threat reduction targets for hydropower outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met or hydropower impacts are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, and to track and periodically evaluate progress, specific metrics related to hydropower impacts (including passage, and flow, temperature, and sediment), population performance (where populations are being reestablished above dams), and action effectiveness will be needed.

    d. Hydropower management actions will support ESU persistence given projected effects of climate change.

B. Overutilization for commercial, recreational, or educational purposes:

1. Harvest-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.

    a. Recovery plan actions addressing harvest-related limiting factors have been substantially implemented, including related research, monitoring, and evaluation actions.

b. The threat reduction targets for harvest outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met or harvest impacts are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, and to track and periodically evaluate progress, specific metrics related to harvest impacts and action effectiveness will be needed.

2. Any other threats related to overutilization for commercial, recreational, or educational purposes (for example, utilization for research purposes) have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.

C. Disease or predation:

1. Predation-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.
    a. Recovery plan actions related to threats from predation by marine mammals, birds, and fish (including predation among salmon species and predation by hatchery-origin salmon on natural-origin salmon) have been substantially implemented, including related research, monitoring, and evaluation actions.
    b. The threat reduction targets for predation outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met or threats from predation are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, and to track and periodically evaluate progress, specific metrics related to predation and action effectiveness will be needed.
2. Disease-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.
    a. Hatchery management practices sufficient to limit disease-related threats are being implemented.
    b. Monitoring is in place to detect disease and disease impacts on population status.

D. The inadequacy of existing regulatory mechanisms:

1. Regulatory mechanisms have been maintained and/or established and are being implemented in a way that supports attaining and maintaining the desired status of the ESU/DPS and its constituent populations, as defined by the biological criteria in this recovery plan.
    a. Regulatory programs that govern land use and resource utilization are in place and are adequate to protect salmon and steelhead habitat, including water quality, water quantity, and

stream structure and function, and to attain and maintain the biological recovery criteria in this recovery plan.

b. States have established and protected instream flow levels in a manner consistent with achieving and maintaining the desired status for the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan.

c. Regulatory programs are in place and are adequate to manage fisheries at levels consistent with the biological recovery criteria of this recovery plan.

d. Regulatory, control, and education measures are in place to prevent introductions of non-native plant and animal species.

e. Regulatory programs have adequate funding, prioritization, enforcement, coordination mechanisms, and research, monitoring, and evaluation to ensure habitat protection and effective management of fisheries.

E. Other natural or man-made factors affecting continued existence:

1. Hatchery-related threats have been ameliorated such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.

a. Recovery plan actions related to threats from hatcheries have been substantially implemented, including related research, monitoring, and evaluation actions. Hatchery and Genetics Management Plans are complete for all hatchery programs and NMFS has authorized all programs under the ESA.

b. The threat reduction targets for hatcheries outlined in Sections 6.5, 7.4.2, 7.5.2, 7.6.2, 8.5, and 9.5 of this recovery plan have been met or hatchery impacts are otherwise consistent with the desired status of the ESU/DPS and its constituent populations. To evaluate whether this criterion has been met, specific metrics for evaluating the genetic and ecological risks posed to natural-origin salmon and steelhead by hatchery-origin salmon and steelhead may need to be developed, tracked, and periodically evaluated.

c. Hatchery programs are being operated in a manner consistent with the target status of each population, and appropriate criteria are being used for managing the interaction of hatchery and natural populations, including hatchery-origin fish spawning naturally.

d. Hatcheries are operated using appropriate ecological, genetic, and risk containment measures for (1) release of hatchery juveniles, (2) handling of natural-origin adults, (3) withdrawal of water for hatchery use, (4) discharge of hatchery effluent, and (5) maintenance of fish health during propagation in the hatchery.

e. Monitoring and evaluation plans are in place and being implemented to measure population status, hatchery

effectiveness, and ecological, genetic, and demographic risk containment measures.

2. Other natural or human-caused factors have been accounted for such that they do not limit attainment of the desired status of the ESU/DPS and its constituent populations as defined by the biological criteria in this recovery plan, and such that the desired status will be maintained.

### 3.2.3 Delisting Criteria Conclusion

NMFS will propose to delist the four listed ESUs addressed by this plan when the following criteria are achieved:

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition.

   High probability of stratum persistence is defined as:

   a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

   b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

   c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

   A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria identified in Section 3.2.2 have been met.

The recovery scenarios in Table 3-1 and the associated population-level abundance and productivity goals presented in Sections 6.3, 7.3, 8.3, and 9.3 of this recovery plan illustrate one possible set of scenarios in which these criteria could be met. The criteria stated above represent a point at which delisting is very likely but not necessarily the only scenario under which NMFS would propose to delist. Nothing in these criteria should be understood as precluding a delisting determination under a different scenario, provided that the ESU is no longer in danger of extinction or likely to become endangered within the foreseeable future.

In accordance with our responsibilities under section 4(c)(2) of the Act, NMFS will conduct reviews of status of each ESU at least once every 5 years to evaluate the ESUs'

status and determine whether the ESUs should be removed from the list or changed in status. NMFS will base such evaluations on the best scientific information available at that time.

## 3.3 Achieving Broad Sense Goals after Delisting

NMFS is supportive of the broad sense recovery goals in the management unit plans and believes that the most expeditious way to achieve them is by achieving viability of natural populations and delisting. Upon delisting, NMFS will work with co-managers and local stakeholders, using our non-ESA authorities, to pursue broad sense recovery goals while continuing to maintain robust natural populations.

# 4. Regional Limiting Factors and Strategies

The reasons for a species' decline are generally described in terms of limiting factors and threats. Limiting factors are biological, physical, or chemical conditions and associated ecological processes and interactions that limit a species' viability. Threats are human activities or natural events, such as floodplain development or drought, that cause or contribute to limiting factors.[1] A single limiting factor may be caused by one or more threats. Likewise, a single threat may cause or contribute to more than one limiting factor and may affect more than one life stage. In addition, the impact of past threats may continue to contribute to current limiting factors through legacy effects. For example, current high water temperature could be the result of earlier riparian practices that removed vegetation from the streambank. Or the effects of previous harvest practices may be evident in the relatively small number of life history strategies that currently exist among salmon and steelhead. Designing effective recovery strategies and actions requires an understanding of the range and impact of limiting factors and threats affecting the species, across its entire life cycle.

Addressing multiple ESUs in a single recovery plan presents an opportunity to evaluate limiting factors and threats at the regional scale, discern large-scale patterns in ecological conditions, and identify regional approaches to recovery. This regional, multi-species perspective is useful in understanding the scale and scope of actions needed to recover the four species addressed by this plan; it also should aid in identifying recovery approaches that provide maximum biological benefit and make effective use of limited resources. Toward that end, this chapter takes a subdomain-scale look at recovery. The chapter gives overviews of limiting factors, at the regional scale, that have affected Lower Columbia River salmon and steelhead and describes regional strategies to address the specific limiting factors identified and analyzed in the management unit plans (see Chapters 6 through 9). The regional strategies are general approaches that either will benefit multiple ESUs or can be applied in ways that target the specific needs of each species. Chapters 6 through 9 supplement the regional strategies with complementary strategies that provide greater specificity at the species and stratum levels.

The regional strategies also highlight the need for domain-scale coordination to implement effective recovery strategies in tributary habitat, estuary habitat, hydropower, hatcheries, harvest, and ecological interactions. Coordination needs are discussed in Chapter 11, "Implementation."

## 4.1 Tributary Habitat

Historically, tributary habitat in the ranges of the Lower Columbia River salmon ESUs and steelhead DPS supported millions of fish in populations that were adapted to the characteristics of individual watersheds. Stream channels contained abundant large wood from the surrounding riparian forests that helped structure pools and create

[1] In this recovery plan, the term limiting factors is used to indicate the full range of factors that are believed to be affecting the viability of salmon and steelhead, and not to indicate the single factor that is most limiting.

complex habitat in streams. Beaver activity also contributed to diverse instream habitats, with deep pools and strong connections to floodplains. Water temperatures sufficient to support salmon and steelhead throughout the year were common. Upland and riparian conditions allowed for the storage and release of cool water during the dry summer months and provided sufficient shade to keep water temperatures cool. Extensive and abundant riparian vegetation armored streambanks, thus shading the water, protecting against erosion, and supporting an abundant food supply. Dynamic patterns of channel migration in floodplains continually created complex channel, side-channel, and off-channel habitats. Over the last 150 years, tributary habitat conditions have been severely degraded.

### 4.1.1 Tributary Habitat Limiting Factors and Threats

Tributary habitat degradation from past and/or current land and water use is a limiting factor for all Lower Columbia River salmon and steelhead populations. Widespread development and other land use activities have disrupted watershed processes, reduced water quality, and diminished habitat quantity, quality, and complexity in most of the lower Columbia River subbasins. Past and/or current land use or water management activities have adversely affected stream and side channel structure, riparian conditions, floodplain function, sediment conditions, and water quality and quantity, as well as the watershed processes that create and maintain properly functioning conditions for salmon and steelhead (LCFRB 2010a, ODFW 2010). Specific activities and their impacts include the following:

- Logging and other forest management practices. Logging on unstable slopes and in riparian areas has led to the degradation of watershed processes. Improperly located, constructed, or maintained forest roads have disrupted stream flow patterns and sediment supply processes, disconnected streams from floodplains, and, in riparian areas, reduced wood recruitment to streams. The historical use of splash dams to transport logs reduced instream structure and available spawning gravel in several stream systems. Impacts continue in many areas, and the legacy of historical practices will continue for some time.

- Agricultural activities. Agricultural activities have diminished overall habitat productivity and connectivity and degraded riparian areas and floodplains in many areas of the lower Columbia region, especially along lowland valley bottoms. Historical floodplain habitats have been lost through levee construction and the filling of wetlands. Runoff from agricultural lands where pesticides, herbicides, and fertilizers are applied has reduced water quality. Water withdrawal for irrigation has altered stream flow and raised water temperatures. Livestock grazing has affected soil stability (via trampling), reduced streamside vegetation (via foraging), and delivered potentially harmful bacteria and nutrients (animal wastes) to streams.

- Construction of fish passage barriers. The main barriers in lower Columbia watersheds are dams and culverts, with occasional barriers such as irrigation diversion structures, fish weirs, beaver dams, road crossings, tide gates, channel alterations, and localized temperature increases (LCFRB 2010a). Although dams are responsible for the greatest share of blocked habitat, inadequate culverts make up the vast majority of all barriers (LCFRB 2010a). Many barriers have been corrected,

but a substantial number of barriers remain. Physical and thermal barriers limit access to spawning and rearing habitats in some areas. Hatchery structures also sometimes act as passage barriers in tributaries (ODFW 2010, LCFRB 2010a). (See Section 4.3 for information on passage issues at hydropower dams and Section 4.4.1.3 for more information on hatchery structures.)

- Urban and rural development. Development has diminished overall habitat productivity and connectivity and led to the degradation of riparian and floodplain conditions and an increase in surface water runoff from cities and towns. The drainage network from roads, ditches, and impervious surfaces alters the hydrograph and delivers sediment and contaminants to streams, thus reducing water quality and affecting the health and fitness of salmonids and other aquatic organisms. Loss of riparian vegetation to development has increased stream temperatures, and bank hardening and channelization of streams have simplified habitat and altered flow. Water withdrawal for municipal uses has contributed to altered stream flows and increases in water temperatures.

- Mining. Sand and gravel mining along some lower Columbia streams has altered instream substrate and sediment volumes (ODFW 2010).

Together these factors have reduced the amount and quality of spawning and rearing habitats available to Lower Columbia River salmon and steelhead, severed access to other historically productive habitats, and degraded watershed processes and functions that once created healthy ecosystems for salmon and steelhead production. Today, many streams have lower pool complexity and frequency compared to historical conditions. Channels also lack the complex structure needed to retain gravels for spawning and invertebrate production. Also missing from many channels is the connectivity with shallow, off-channel habitat and floodplain areas that once provided productive early-rearing habitat, flood refugia and overwintering habitat, and cover from predators. In many areas, contemporary watershed conditions are so different from those under which native fish species evolved that they now pose a significant impediment to achieving recovery (LCFRB 2010a, ODFW 2010).

Table 4-1 lists common tributary habitat limiting factors that adversely affect populations of Lower Columbia River salmon and steelhead.[2] As the table illustrates, Lower Columbia River salmon and steelhead commonly are limited by the shape, structure, and connectivity of the waterways they use; the amount of water (and thus habitat) available to them at different times of year; and the suitability of gravel for spawning. The fact that many of the most common limiting factors are related to basic ecosystem functions underscores the need for fundamental, widespread improvement in watershed processes through much of the lower Columbia Basin. Another message is that any actions implemented to address these most common limiting factors have the potential to benefit more than one ESU, especially when ESUs have overlapping habitat preferences (such as lower elevation off-channel rearing habitat used by both chum and

[2] Table 4-1 uses terminology from a "data dictionary" of ecological concerns developed by the NMFS Northwest Fisheries Science Center but is based on characterizations of limiting factors and threats in the management unit plans, as compiled in the species-specific NMFS limiting factors "crosswalk" tables presented in Appendix H (see also Section 5.4 for a description of the data dictionary and crosswalk tables).

fall Chinook salmon). Even so, Table 4-1 does not represent all of the limiting factors that affect any particular ESU, or even necessarily the most important limiting factors for a particular ESU or population; when implementing recovery actions, it is important to consider the specific needs of each ESU or population to ensure that important but less common limiting factors are not overlooked (see Chapters 6 through 9).

It also is worth noting that some of the limiting factors in Table 4-1, such as hydrology and sediment conditions, or loss of riparian cover, temperature, and sediment supply, are interrelated. This raises the possibility of synergistic or compounded effects of recovery actions. Future monitoring may clarify the nature of such effects and provide opportunities for adaptive management to ensure that such effects are realized.

**Table 4-1**
*Common Tributary Habitat Limiting Factors and Threats*

| Limiting Factor | Subcategory | Associated Threats |
|---|---|---|
| Riparian conditions | | Past/current land use practices |
| Peripheral and transitional habitats | Side channel and wetland conditions | Past/current land use practices<br>Transportation corridor development and maintenance |
| | Floodplain condition | Past/current land use practices<br>Transportation corridor development and maintenance |
| Impaired channel structure and form | Bed and channel form | Past/current land use practices<br>Transportation corridor development and maintenance<br>Inundation from Bonneville Reservoir |
| | Instream structural complexity | Past/current land use practices<br>Transportation corridor development and maintenance<br>Inundation from Bonneville Reservoir |
| Sediment conditions[3] | Decreased sediment quantity (impaired sediment/sand routing and gravel recruitment) | Dams |
| | Increased sediment quantity | Past and/or current land use practices (e.g., rural roads)<br>Transportation corridor development and maintenance |
| Water quality | Elevated water temperature | Land uses that impair riparian function/decrease stream flow<br>Large dam reservoirs |

[3] The limiting factors crosswalk also identified turbidity as a common limiting factor (as a subcategory of the water quality limiting factor); however, when NMFS developed the limiting factors crosswalk, it indicated turbidity as a limiting factor for every population affected by sediment conditions, because the management unit plans did not necessarily distinguish between sediment and turbidity. The crosswalk results for turbidity should be validated at some point in the future and are not included in Table 4-1 or the species-specific limiting factor summary tables in Chapters 6 through 9 because of this uncertainty.

| Limiting Factor | Subcategory | Associated Threats |
|---|---|---|
| Water quantity | Altered hydrology<br>Decreased water quantity/downstream flows<br>Altered flow timing | Low-head hydro diversions<br>Upslope land uses<br>Withdrawals for irrigation, hatchery, or municipal uses<br>Hydropower dams |

### 4.1.2 Regional Strategy for Tributary Habitat

To address the limiting factors and threats described above and in Chapters 6 through 9, the regional tributary habitat strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific projects that will protect habitat or provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Although many habitat-related actions already have been undertaken, current activities do not reflect the scale of habitat improvements needed. Recovery of the listed species will require concerted efforts to protect remaining areas of favorable habitat and restore habitat quality in significant historical production areas. The management unit plans place a high value on protecting currently functioning habitat as a means of retaining and building out from current production. However, restoration also is essential because current habitat in most subbasins is inadequate to support viable populations of Lower Columbia River salmon and steelhead. Federal lands will play a significant role in providing and protecting anchor habitats, but substantial improvements also are needed in marginal areas of potentially productive habitat (LCFRB 2010a). Especially at low elevations, much of the land is in private ownership, where restoration activities are likely to be challenging and expensive.

Representative actions to address the most common limiting factors affecting Lower Columbia River salmon and steelhead are shown in Table 4-2.

There is an immediate need to develop prioritization frameworks and get additional targeted, site-specific protection and restoration actions, as well as programmatic approaches, on the ground as soon as possible, especially because the benefits of some habitat actions will take years to accrue. Some prioritization work has already occurred. The Washington management unit plan, for instance, has prioritized tributary actions by stream reach based on the needs of all populations in a particular watershed (LCFRB 2010a). The Oregon management unit plan has done some prioritization based on where an action will have the greatest beneficial effect and where implementation is most feasible (ODFW 2010), but in many Oregon watersheds additional assessment is needed to determine protection and restoration priorities at a meaningful spatial scale (ODFW 2010). The White Salmon management unit plan also identifies areas that are a high priority for habitat actions but points to the need for additional information to identify and prioritize specific habitat actions (NMFS 2013). For example, now that Condit Dam

has been removed,[4] habitat conditions downstream of the dam site, and in the area previously occupied by Northwestern Lake, will need to be assessed and priority restoration actions identified (NMFS 2013). In addition, site-specific protection and restoration actions need to be prioritized at the subdomain scale, funding sources need to be coordinated, and benchmarks established by which to assess progress in implementation and evaluate biological benefits. In these efforts, opportunities to consider ecosystem function and benefits need to be balanced with individual species' needs.

**Table 4-2**
*Representative Actions to Address Limiting Factors Affecting Most Populations*

| Limiting Factor | Subcategory | Representative Actions |
|---|---|---|
| Impaired channel structure and form | Bed and channel form | Restore degraded off-channel habitats<br>Streamline delivery of large wood to restoration sites<br>Restore degraded riparian areas through planting or fencing |
| | Instream structural complexity | Restore riparian areas to improve water quality, provide long-term supply of large wood to streams, and reduce impacts that alter other natural processes |
| Sediment conditions and water quality[5] | Decreased sediment quantity (impaired sediment/sand routing and gravel recruitment) | Place gravel for spawning (below dams)<br>Remove Little Sandy River diversion (completed) |
| | Increased sediment quantity (turbidity from excessive fine sediment) | Conduct sediment source analyses and reduce inputs<br>Develop/implement stormwater management plans for urban areas and roads<br>Identify and rectify problem legacy roads |
| Water quantity | Altered hydrology<br>Decreased water quantity/downstream flows<br>Altered flow timing | Protect intact riparian areas via easements and acquisition<br>Explore cooperative water conservation measures<br>Restore connectivity to small tributaries<br>Restore degraded off-channel and riparian habitat<br>Establish minimum ecosystem-based instream flows<br>Identify and halt illegal water withdrawals |

Watershed-based actions of particular importance will include efforts to restore hydrologic, riparian, and sediment processes. Accordingly, the management unit plans identify systemic actions related to land use planning and management. In the Washington plan, such actions include managing forest lands to protect and restore watershed processes, managing growth and development to protect watershed processes and habitat conditions, and protecting and restoring stream corridor structure and function, hillslope processes, floodplain function, and channel migration (LCFRB

[4] Condit Dam was breached in October 2011 and completely removed in September 2012.
[5] The data dictionary and limiting factors crosswalk consider turbidity as a subcategory of the water quality limiting factor and thus separately from sediment conditions, but the two limiting factors are presented together in this table because their mechanisms, causes, and effects in the lower Columbia River basin are so similar.

2010a). The Oregon plan includes actions to (1) develop land management scenarios that address hydrograph changes resulting from altered runoff and climate change, (2) protect and restore riparian areas to provide long-term supplies of large wood to streams, (3) develop stormwater management plans, (4) conduct sediment source analyses and implement needed actions, (5) ensure that future development impacts in the 100-year floodplain are either low-impact or are mitigated, and (6) prohibit development of new dikes, levees, and floodwalls in the 100-year floodplain unless they will not increase flood volume, size, and/or intensity (ODFW 2010).

Managing the impacts of growth and development on watershed processes and habitat conditions will be key to protecting and improving habitat conditions for Lower Columbia River salmon and steelhead. Accordingly, the recovery strategy proposes actions such as managing urban stormwater and agricultural runoff to reduce contaminants in streams (LCFRB 2010a), limiting water withdrawals to maintain instream flows (LCFRB 2010a) and temperatures, and using land use planning to encourage low-impact development and to direct future development away from ecologically sensitive areas (LCFRB 2010a, ODFW 2010 ).

Subbasins vary in the role they will play in recovery, with some subbasins targeted to support several primary populations from different ESUs,[6] some that will not support any primary populations,[7] and some targeted to support a mix of primary and contributing populations. Table 4-3 shows subbasins targeted in the management unit plans to support three or more primary populations. Together, these are the subbasins used by most of the core and genetic legacy populations from the Lower Columbia River ESUs. These subbasins will play a key role in the recovery of multiple species and populations and are where much of the improvements in population status will take place, across ESUs.

[6] As described in Section 3.1.3, primary populations are those targeted for high or very high probability of persistence, based on their historical productivity, their genetic contribution to the ESU, the geographical distribution of primary populations within the ESU (to reduce catastrophic risk), and the feasibility of improving a given population's status.

[7] Subbasins that the management unit plans designate as having no primary populations under the recovery scenario are the Youngs Bay, Big Creek, Tilton, and Salmon Creek. Because the Youngs Bay and Big Creek subbasins are terminal fishing areas, the impact of hatchery production and harvest on natural-origin fish in these subbasins is expected to remain high. The Tilton subbasin has passage barriers to its upper reaches, along with habitat degradation in its lower reaches. Habitat degradation also is an issue in the heavily urbanized Salmon Creek subbasin, where urban and rural development pressures are increasing. In the White Salmon subbasin, recovery prospects are highly uncertain and recovery is expected to take considerable time as habitat recovers from the impacts of Condit Dam, which was breached in October 2011 and completely removed in September 2012. Uncertainties include the habitat response to dam breaching and removal and the success of recolonization or reintroduction efforts. In addition, the Lower Cowlitz subbasin has only one primary population—coho salmon—because of passage barriers to upper reaches, the largely non-forested state of the lower reaches, and growing cities and towns; however, some habitat in the Lower Cowlitz subbasin will support primary populations outmigrating from upstream subbasins (i.e., the Upper Cowlitz, Cispus, Toutle, and Coweeman).

**Table 4-3**
*Subbasins Targeted to Support Three or More Primary Populations*

| Ecozone | Subbasin | Primary Populations |
|---|---|---|
| Coast | Elochoman | Fall Chinook, chum, coho |
| | Clatskanie | Fall Chinook, chum, coho |
| | Scappoose | Fall Chinook, chum, coho |
| Cascade | Coweeman | Fall Chinook, winter steelhead, coho |
| | SF Toutle | Fall Chinook, winter steelhead, coho |
| | NF Toutle | Fall Chinook, winter steelhead, coho |
| | Cispus | Spring Chinook, winter steelhead, coho |
| | Upper Cowlitz | Spring Chinook, winter steelhead, coho |
| | NF Lewis | Fall Chinook, late-fall Chinook, spring Chinook, chum |
| | EF Lewis | Fall Chinook, chum, winter steelhead, summer steelhead, coho |
| | Washougal | Fall Chinook, chum, summer steelhead |
| | Sandy | Late-fall Chinook, spring Chinook, chum, winter steelhead, coho |
| Gorge | Lower Gorge tribs | Chum, winter steelhead, coho |
| | Hood | Fall Chinook, spring Chinook, winter steelhead, summer steelhead, coho |

NMFS encourages implementers of this recovery plan to carry out tributary habitat protection and restoration actions specified in the Oregon, Washington, and White Salmon management unit plans in a manner that addresses limiting factors at the population scale. NMFS also encourages relevant entities to revise or add regulatory and/or incentive programs where monitoring indicates that habitat function and conditions are not improving. Particularly relevant are programs that address activities in floodplains and riparian areas and that affect sedimentation and other watershed processes.

NMFS welcomes opportunities to work with implementers to pursue ESA regulatory assurances to ensure that programs meet the conservation needs of salmon and steelhead. Among non-federal programs, for example, NMFS has determined that Washington's habitat conservation plans for state-owned forest land and its Forest Practices Rules for private forest land meet conservation needs for salmon and steelhead. (There are two distinct habitat conservation plans in Washington: one covering state lands in Washington state [west of the Cascades crest], and a second applied to forest practices on private and industrial forestlands statewide.) NMFS' view is that some state land management and regulatory programs (e.g., state forest management and forest practice rules in Oregon and regulation of certain agricultural practices in Oregon and Washington) do not provide adequate certainty that they will protect and restore salmon and steelhead habitat in a manner sufficient to recover the subject ESA-listed species. Where population-level habitat monitoring indicates statistically significant trends in degradation of key habitat features, the Oregon management unit plan calls for encouraging new or revised regulatory measures to

eliminate further degradation of key habitat features, protect existing high-quality areas, and allow long-term passive restoration (ODFW 2010); the management unit plan does not identify a specific implementing entity for this action. NMFS considers this action a high priority and intends to work with ODFW and other appropriate agencies on its implementation.

Among federal programs, since 1994, for example, land management by the U.S. Forest Service and Bureau of Land Management in western Oregon has been guided by the Northwest Forest Plan (U.S. Department of Agriculture and U.S. Department of Interior 1994). The aquatic conservation strategy in this plan includes elements such as designated riparian management zones, activity-specific management standards, watershed assessment, watershed restoration, and identification of key watersheds (USDA and USDI, 1994). The Northwest Forest Plan has large riparian management zones and relatively protective, activity-specific management standards (USDA and USDI, 1994). NMFS considers the Northwest Forest Plan, when fully implemented, sufficient to provide for the habitat needs of Lower Columbia River salmon and steelhead and Columbia River chum on federal lands. (Although maintaining high-quality habitat on federal lands is necessary for the recovery of these species, recovery is unlikely unless habitat also can be improved in streams with high potential on non-federal lands.)

Many other federal programs are also important to protection and restoration of salmon and steelhead habitat. In addition to working with agencies to fulfill their ESA section 7(a)(2) responsibilities, NMFS welcomes opportunities to work with federal agencies to develop ESA section 7(a)(1) conservation programs that provide a more localized approach to priority threats and limiting factors.

For information on stratum-level tributary habitat strategies, see Sections 6.6.2, 7.4.3.2, 7.5.3.2, 7.6.3.1, 8.6.2, and 9.6.1.

## 4.2 Estuary Habitat

Habitat conditions in the Columbia River estuary and plume are important to the survival of all Columbia Basin salmon and steelhead during critical rearing, migration, and saltwater acclimation periods in their life cycle. For purposes of this recovery plan, the Columbia River estuary is defined as extending from the mouth of the Columbia River 146 miles upstream to Bonneville Dam and includes the Willamette River below Willamette Falls and the tidally influenced portions of other tributaries below Bonneville Dam. The Columbia River plume is generally defined by a reduced-salinity contour near the ocean surface off the immediate coasts of both Oregon and Washington and extending outward to the continental shelf.

The estuary and plume provide salmon and steelhead with a food-rich environment where they undergo the physiological changes needed to make the transition to and from saltwater and achieve the growth needed to bolster their marine survival (NMFS 2011a, LCFRB 2010a). Areas of adjacent habitat types distributed across the estuarine salinity gradient may be necessary to support annual migrations of juvenile salmonids (Bottom et al. 2005, cited in LCFRB 2010a). Observations of juveniles moving from low-tide refuge areas in deeper channels to salt marsh habitats at high tide and back again

(Healey 1982, cited in LCFRB 2010a) reinforce the belief that access to suitable low-tide refugia near marsh habitat is an important factor in production and survival of salmonid juveniles in the Columbia River estuary. Ocean-type salmonids in particular (i.e., fall Chinook and chum salmon) rely on the estuary for rearing opportunities. Ocean types typically spend weeks to months in the estuary, making use of shallow, vegetated habitats such as marshes and tidal swamps (NMFS 2011a). The plume—a unique low-salinity, high-productivity environment that extends well into the ocean—appears to serve a similar function for stream-type salmonids, offering feeding opportunities for coho salmon, spring Chinook salmon, and steelhead and distributing juveniles in the coastal environment (NMFS 2011a). These species typically make more use of the plume than ocean types do, spend less time in the estuary, and use mostly deeper, main-channel estuarine habitats rather than shallow vegetated wetlands (NMFS 2011a). However, feeding and refuge areas in the estuary may be important even for salmonid species that move through the estuary relatively quickly (LCFRB 2010a).

In addition, the physical refugia and turbidity in the estuary and possibly also the plume historically helped protect both ocean- and stream-type juveniles from predators (NMFS 2011a).

For more information on the Columbia River estuary, see the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a).[8]

### 4.2.1 Estuary Habitat Limiting Factors and Threats

Currently a lack of habitat opportunity and reduced habitat quality limit the viability of salmon and steelhead in the Columbia River estuary and plume. The amount and accessibility of in-channel, off-channel, and plume habitat have been reduced as a result of habitat conversion for agricultural, urban, and industrial uses, hydroregulation and flood control, channelization, and higher bankfull elevations, which have been facilitated by diking, dredging, and filling. Overbank flooding that normally would aid juveniles in accessing off-channel refugia and food resources has been virtually eliminated, and sediment transport processes that structure habitat (and offer protection from predators) have been impaired (NMFS 2011a). Access to up to 77 percent of historical tidal swamps and many other peripheral wetlands has been eliminated, and the surface area of the estuary has decreased by approximately 20 percent over the past 200 years (Fresh et al. 2005). Similarly, over roughly the last century the annual mean river flow through the estuary has declined by about 16 percent and peak spring flows have declined about 44 percent (Jay and Naik 2002 as cited in NMFS 2011a).

[8] The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) synthesizes recently available information on the Columbia River estuary and plume to identify and analyze (1) limiting factors and threats in the estuary and plume that affect the viability of salmon and steelhead populations, (2) management actions whose implementation would reduce the threats and thus increase survival of salmon and steelhead during their time in the estuary, (3) the estimated cost of implementing each action over a 25-year period, and (4) monitoring, research, and evaluation needs related to the estuary and plume. Key source documents for the estuary module included two NMFS technical memoranda (Bottom et al. 2005 and Fresh et al 2005) and the subbasin plan for the lower Columbia River estuary and mainstem (Northwest Power and Conservation Council 2004a). Information from these sources was supplemented by input from NMFS' Northwest Fisheries Science Center and Northwest Regional Office, the Lower Columbia Estuary Partnership, and the Lower Columbia Fish Recovery Board. For more on the estuary module, see Section 1.5.3.

Some reductions in Columbia River flow are attributable to water withdrawals for irrigation and commercial, industrial, municipal, domestic, and other human uses. Irrigation needs account for approximately 96 percent of surface water withdrawals and 75 percent of groundwater withdrawals (National Research Council 2004). In total, water withdrawals have reduced flows of the Columbia River by 7 percent since the latter part of the nineteenth century (Jay and Kukulka 2003).

Meanwhile, the quality of the habitat available to salmon and steelhead in the estuary has been compromised. Water temperatures above the upper thermal tolerance range for salmon and steelhead are occurring earlier and more often (NMFS 2011a) and are likely to continue to climb as a result of global climate change (Independent Scientific Advisory Board 2007a, as cited in NMFS 2011a). A variety of toxic contaminants have been found in water, sediments, and salmon tissue in the estuary at concentrations above the estimated thresholds for health effects in juvenile salmon. These contaminants include polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), DDT, and copper (Lower Columbia River Estuary Partnership 2007). Pesticides in current use also have been detected in the estuary, along with emerging contaminants such as pharmaceuticals, personal care products, and brominated fire retardants (Lower Columbia River Estuary Partnership 2007). Although the effects of emerging contaminants on salmon and steelhead are not well understood, these compounds appear to pose risks to salmonid development, health, and fitness through endocrine disruption, bioaccumulative toxicity, or other means. Toxic contaminants are widespread in the estuary, both geographically and in the food chain (Lower Columbia River Estuary Partnership 2007).

Construction of revetments, disposal of dredged material, removal of large wood, and reductions in flow in the estuary have altered the diet of juvenile salmon in the estuary by eliminating much of the vegetated wetlands that historically supplied insect prey for juvenile salmonids and macrodetrital inputs to the estuarine food web. The shift in diet has been compounded by increased microdetrital inputs to the estuary; microdetrital inputs originate in decaying phytoplankton delivered from upstream reservoirs and nutrient inputs from urban, industrial, and agricultural development. The microdetrital-based food web may be less efficient for salmon and steelhead and favor other fish species in the estuary, such as American shad. It is likely that estuarine food web dynamics are being furthered altered by the presence of native and exotic fish, introduced invertebrates, invasive plant species, and thousands of over-water and instream structures, which alter habitat in their immediate vicinity. These and other changes in habitat have left the estuary and plume in a degraded state compared to historical conditions (NMFS 2011a).

In addition, current habitat conditions in the estuary and plume support increased predation on salmonids by northern pikeminnow, pinnipeds, Caspian terns, and cormorants, and juvenile salmon and steelhead in the estuary are subject to mechanical hazards from dredging activities, ship ballast intake, and beach stranding as a result of ship wakes (NMFS 2011a).

The degraded habitat conditions in the estuary and plume affect the abundance, productivity, spatial structure, and diversity of ESA-listed salmon and steelhead and have led to estuarine habitat issues being identified in the Oregon and Washington

management unit plans as one of six general categories of threats that limit the viability of Lower Columbia River Chinook, coho, and steelhead and Columbia River chum salmon. Both management unit plans cite water quantity and flow timing, impaired sediment and sand routing, altered channel structure, and loss or degradation of peripheral and transitional habitats in the Columbia River estuary and plume as primary limiting factors that affect all Lower Columbia River Chinook, coho, and steelhead and Columbia River chum salmon juveniles. Management unit recovery planners estimated baseline anthropogenic mortality in the estuary and plume—excluding mortality attributable to predation—at between 9 and 50 percent, depending on species and population; for most populations, the estimates range from 10 to 32 percent (see ODFW pp. 169-200 and LCFRB 2010a pp. 6-17, 6-38, 6-50, and 6-66). These estimates were based in part on mortality estimates in the estuary module (NMFS 2011a).

Additional information about limiting factors, threats, and mortality in the Columbia River estuary and plume is available in Chapters 3 and 4 of the estuary module (NMFS 2011a), ODFW (2010) pp. 88-90, and LCRFB (2010a) pp. 3-33 through 3-47.

### 4.2.2 Regional Strategy for Estuary Habitat

Actions and strategies presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats are consistent with those in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a), which describes and analyzes actions to benefit all Columbia Basin salmon and steelhead species, including the Lower Columbia River ESUs. In general, estuary habitat strategies focus on providing adequate off-channel and intertidal habitats, such as tidal swamp and marsh; restoring habitat complexity in areas modified by agricultural or rural residential use; decreasing exposure to toxic contaminants; and lowering late summer and fall water temperatures. This will be accomplished over the long term by restoring hydrologic, sediment, and riparian processes that structure habitat in the estuary. Representative actions include protecting and restoring high-quality off-channel habitats and riparian areas; identifying and reducing current sources of pollutants; restoring contaminated sites; adjusting the timing, magnitude, and frequency of flows[9]; and breaching and lowering dikes and levees. Together, these actions are expected to increase the complexity and accessibility of estuarine habitat and improve water quality and flow patterns in the estuary and, potentially, the plume. A host of additional actions, such as preventing new introductions of invasive species, also are expected to improve habitat conditions in the estuary, to a lesser degree.

Because the mechanisms of estuary habitat impacts and the techniques for reducing them are poorly understood, estuary habitat actions will need to be implemented under an adaptive management framework. Both the estuary module and the management unit plans identify research needs to reduce critical uncertainties and increase the effectiveness of actions (see Table 5-6 of NMFS 2011a, pp. 233-238 of ODFW 2010, and p. 9-72 of LCFRB 2010a).

[9] Adjusting timing, magnitude, and frequency of flows would be limited by international treaties, the need for flood control, fish management objectives, and power production. However, even slight modifications in the flow regime have the potential to provide significant ecosystem benefits.

An aggressive, strategic approach needs to be developed for implementation of actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The estuary module refrains from explicitly prioritizing habitat actions because it considers all of the management actions it identifies as necessary in improving the survival of juvenile salmonids in the Columbia River estuary and plume. But the module does identify priority reaches for each action and offers several analyses intended to inform future decisions about prioritization (i.e., actions likely to be most beneficial to stream-type salmonids, those that will benefit ocean types, and those that are most cost-effective; see Tables 7-2, 7-3, and 7-5 of NMFS 2011a). These analyses take into account the probable implementation constraints for each action (see Table 5-6 of NMFS 2011a). In addition, the module identifies a need to determine near-term implementation priorities by developing a 5-year implementation plan that provides specificity and certainty regarding near-term actions. For many actions, additional assessment is needed to determine implementation priorities and specific benefits to Lower Columbia River salmon and steelhead.

Developing implementation priorities for estuarine habitat actions should include establishment of milestones or expected trends in improved habitat condition in high-priority intertidal areas, which are particularly important for ocean-type salmon (i.e., fall Chinook and chum salmon). Less is known about the habitat needs of chum salmon than those of other ESUs addressed in this recovery plan, and the management unit plans call for habitat assessments to learn more on this subject. Yet what is known points to overlapping habitat needs with fall Chinook salmon, especially for rearing habitat. A topic to be investigated is whether Coast- and Cascade-stratum chum salmon populations, like fall Chinook salmon, make heavy use of the tidal portions of tributaries at their confluence with the mainstem Columbia. The Washington management unit plan notes that lower tidal reaches of streams were not typically assigned a high priority for habitat actions in the EDT-based watershed assessments, but these areas have been identified as critical rearing areas for both fall Chinook and chum salmon (LCFRB 2010a).

## 4.3 Hydropower

The Columbia Basin has more than 450 dams, which are managed for hydropower, flood control, and other uses. Together these dams provide active storage of 42 million acre-feet of water, with dams in Canada accounting for about half of the total storage (Northwest Power and Conservation Council 2001, as cited in NMFS 2011a). Within the United States, 14 multi-purpose hydropower projects operate as a coordinated system in the Columbia Basin. Bonneville Dam is the only mainstem hydropower facility within the geographic range of Lower Columbia River salmon and steelhead, but flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect habitat in the lower Columbia River mainstem and estuary, and, potentially, the plume. In addition, significant tributary hydropower dams are located on the Cowlitz and Lewis rivers in Washington and the Willamette, Clackamas, and Sandy rivers in Oregon. Condit Dam, on the White Salmon River, was breached in October 2011 and completely removed in September 2012.[10] The impacts of hydropower facility construction and operation on Lower Columbia salmon and

[10] Powerdale Dam, on the Hood River, was removed in 2010.

steelhead occur both locally (at, above, and immediately below dams) and downstream, in the Columbia River estuary and, potentially, the plume.

### 4.3.1 Hydropower Limiting Factors and Threats

Hydropower limiting factors and threats can be categorized as those related to reservoirs and structures (including passage and habitat access impacts) and those related to flow modifications. These are described briefly below.

#### *4.3.1.1 Reservoir-Related or Structural Impacts*

Dam construction on the lower Columbia River and its tributaries has caused habitat loss by converting riverine habitat to large impoundments of slow-moving water and flooding upriver deltas, wetlands, and floodplains (ODFW 2010).

The impoundment of water in large storage reservoirs in the interior Columbia Basin and operations at mainstem hydropower projects in the lower Columbia Basin has contributed to increased water temperatures during the late summer and fall in the Columbia River, including the lower Columbia River mainstem and estuary. Even when elevated temperatures do not cause direct mortality, they can cause adverse physiological and behavioral effects and may enhance conditions for warm-water fish that prey on juvenile salmonids (NMFS 2011a).

Impoundments also alter food webs and enhance opportunities for some predators. In Bonneville Reservoir and just downstream of Bonneville Dam, a variety of fish species—northern pikeminnow, walleye, smallmouth bass, and salmonids—prey on juvenile salmon and steelhead. In addition, adult spring Chinook salmon and steelhead attempting to pass above Bonneville Dam are subject to predation by seals and sea lions that congregate at the dam (U.S. Army Corps of Engineers 2011a). For more on predation, see Section 4.6.1.1.

In addition, water can become supersaturated with atmospheric gases (primarily nitrogen) when spilled over high dams. These high concentrations of gases are absorbed into a fish's bloodstream during respiration. When the gas comes out of solution, bubbles may form and subject the fish to gas bubble disease, which can cause direct mortality or increase susceptibility to disease or predation (LCFRB 2010a). Dam operations have been modified to reduce what once were high dissolved gas levels, but some salmonid mortality continues to be associated with exceptionally high river flows (NMFS 2000a).

**Impaired Fish Passage in the Columbia River Mainstem**

Bonneville Dam on the Columbia River mainstem acts as a partial migration barrier to Lower Columbia River salmon and steelhead populations that originate above the dam—specifically, Upper Gorge, Hood River, and White Salmon populations. Both downstream-migrating juveniles and upstream-migrating adults experience delay, injury, and mortality while trying to pass the dam.

Although fish ladders provide for upstream passage of adult salmon and steelhead, historically—and during the baseline period for this recovery plan—they have not been completely effective (LCFRB 2010a). More recently in the lower Columbia River mainstem, average survival rates of adults at Bonneville Dam have been estimated at approximately 99 percent for spring Chinook salmon and steelhead and 97 percent for fall Chinook, coho, and chum salmon (NMFS 2008a).

Downstream fish passage at Bonneville Dam is complex, with two passage routes at each of two powerhouses, plus an unattached spillway. Outmigrating juveniles experience different mortality rates depending on whether passage occurs via turbines, spill, or a fish bypass system. NMFS estimates that recent average survival of juveniles from Lower Columbia River ESUs at Bonneville Dam is between 90 and 95 percent, depending on species (NMFS 2008a).

**Impaired Fish Passage in Tributaries**

Tributary dams create fish passage barriers that limit habitat connectivity and access to spawning and rearing habitats for some Lower Columbia River salmon and steelhead. As with Bonneville Dam, tributary dams can cause mortality of out-migrating juveniles, delay migration of returning adult salmon and steelhead, and hinder or totally block access to historical spawning areas above the dam. Within the lower Columbia recovery planning subdomain, major hydropower systems on the Cowlitz and Lewis rivers in Washington are responsible for the greatest share of blocked habitat access. Tributary dams also restrict fish passage in the Clackamas, Sandy, and White Salmon watersheds.[11] (Although dams are responsible for the greatest share of blocked habitat, inadequate culverts make up the vast majority of all barriers [LCFRB 2010a]; see Section 4.1.1.)

#### *4.3.1.2 Flow-Related Impacts*

Before development of the hydropower system, Columbia River flows were characterized by high spring runoff from snowmelt and regular winter and spring floods. Today, the interception and retention of spring freshets in multiple dams and their use for irrigation, reservoir storage, and other purposes cause flow volumes to the Columbia River estuary to be more uniform throughout the year than they were historically (see Figure 4-1). Over the last century, annual mean flow in the Columbia River estuary has declined, the volume of the spring freshet has dropped by 44 percent, and the timing of the freshet has shifted to 14 to 30 days earlier in the year (Jay and Kukulka 2003). Although changes in flow entering the estuary are due to a combination of factors, including water withdrawals and the effects of climate change, the management unit plans and *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) identify mainstem dams as the primary contributor to flow alterations in the estuary.

[11] Powerdale Dam, on the Hood River, was removed in 2010. Condit Dam, on the White Salmon River, was breached in October 2011 and completely removed in 2012.

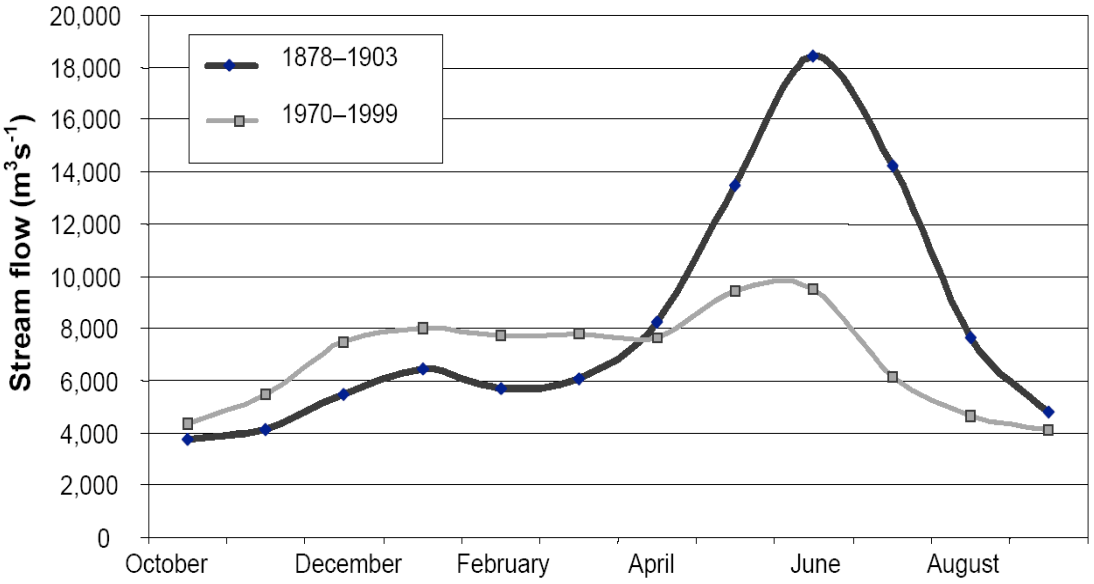


**Figure 4-1.** *Changes in Annual Columbia River Flow*
(Measured at Beaver Army Terminal, near Quincy, Oregon. Source: Bottom et al. 2005).

Flow alterations have disrupted habitat-forming processes such as the recruitment of large woody debris and sediment delivery to the Columbia River estuary. Historically, sediment was delivered to the estuary largely via spring freshets. That vehicle for sediment delivery has been curtailed, and today reservoirs commonly act to trap upstream supplies of fine sediments (NMFS 2011a). Since the late nineteenth century, sediment transport from the interior of the Columbia Basin to the Columbia River estuary has decreased approximately 60 percent (Jay and Kukulka 2003). This has altered deposition and erosion processes that shape estuarine habitat for salmonids.

Together with diking and the placement of dredged materials on or near the shore, flow alterations have also virtually eliminated the overbank flooding that once allowed juvenile salmonids to access large areas of off-channel habitat for refuge and rearing. Without periodic inundation—tidal, seasonal, or annual—much habitat that formerly was used by juvenile salmonids has disappeared or been transformed into different habitat types (NMFS 2011a).

By reducing wetland and foraging habitat, simplifying habitats, and altering sediment inputs, flow alterations have contributed to changes in the estuarine food web, particularly in detrital food sources. The current food web is based on decaying phytoplankton delivered from upstream reservoirs, instead of macrodetrital inputs from plants and animals originating from emergent forest and other wetland rearing areas in the estuary, as was the case historically. The switch from macrodetrital- to microdetrital-based food sources has lowered the productivity of the estuary (Bottom et al. 2005), provided different and possibly less favorable food sources to juvenile salmonids, and concentrated food sources within the estuarine turbidity maximum, in the middle region of the estuary (Bottom et al. 2005). This location is less accessible to ocean-type salmon, such as chum, that use peripheral habitats (LCFRB 2010a).

Both juvenile and adult migration behavior and travel rates are influenced by the changes in river flow. Artificial regulation of flow can stimulate or delay juvenile emigration or adult migration, thereby affecting the timing of juvenile arrival in the estuary and ocean (ODFW 2010, LCFRB 2010a) or adult arrival at spawning areas (LCFRB 2010a).

Rapid diurnal flow fluctuations can cause unintended and adverse redistribution of mainstem spawners, leave redds dewatered, or strand juveniles (LCFRB 2010a). Although daily flow fluctuations as a result of power production occurred in the past and resulted in dewatering of chum redds, a minimum flow now applies from November through April to reduce the potential for such dewatering.

### 4.3.2 Regional Hydropower Strategy

The regional hydropower strategy focuses on hydropower operations on the Columbia River mainstem and has three principal components: (1) improving passage survival at Bonneville Dam for Lower Columbia River populations that spawn above the dam, (2) addressing impacts in tributaries by implementing actions prescribed in Federal Energy Regulatory Commission agreements regarding operation of individual tributary dams, and (3) implementing mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. Actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a) will aid adults and juveniles from the Gorge populations in passing Bonneville Dam. Specific actions include structural improvements, changes in configuration and operations, and development and implementation of year-round fish passage plans for Bonneville Dam.[12] NMFS' estimates of recent survival of lower Columbia River species are shown in Table 4-4. NMFS expected that implementation of actions in the 2008 FCRPS Biological Opinion would improve juvenile salmon and steelhead survival at Bonneville Dam by less than ½ percent, and that the recent high level of adult survival would be maintained at the levels shown in Table 4-4 (NMFS 2008a and 2010a). Consequently, Oregon did not incorporate survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[13] The Washington management unit plan assumed that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement would aid adults and juveniles from all populations originating above Bonneville Dam. However, preliminary information indicates that survival gains for yearling Chinook and steelhead at Bonneville Dam are higher than expected, and that juvenile passage survivals are above 96 percent in both cases (U.S. Army Corps of Engineers 2011b).

In addition, for chum salmon, the regional hydropower strategy will focus on ensuring adequate flows in the Bonneville Dam tailrace and downstream habitats during chum salmon migration, spawning, incubation, and emergence. FCRPS Biological Opinion

[12] For more specificity, see the actions in the 2008 FCRPS Biological Opinion Reasonable and Prudent Alternative (NMFS 2008f).

[13] Hydropower-related threat reductions for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

actions will protect chum salmon spawning areas in the mainstem Columbia River in the area of the Ives Island complex and/or will provide access to Hamilton and Hardy creeks. These areas currently constitute significant spawning areas for the Lower Gorge population.

**Table 4-4**
*Estimated Average Survival Rates of Lower Columbia Salmon and Steelhead Passing Bonneville Dam*

| | Average Survival Rate (%) | |
|---|---|---|
| | Juveniles 2002 – 2009 | Adults 2002 – 2007 |
| Coho salmon | 95.1 | 96.9 |
| Spring Chinook salmon | 95.1 | 98.6 |
| Fall Chinook salmon | 95.1 | 96.9 |
| Chum salmon | 95.1 | 96.9 |
| Steelhead | 90.6 | 98.5 |

Source: NMFS (2008a) and (2010a).

In its management unit plan, Oregon incorporated four actions addressing impacts of the Columbia River hydropower system that are not included in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a) but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead:

- Action 1: Operate lower Columbia reservoirs at minimum operating pool during spring and summer as long as barge transport and irrigation needs are met.
- Action 2: Provide spill to total dissolved gas limits of water quality waivers or biological constraints at all dams, except maximize transportation at Snake River collector projects during lower (10$^{th}$ percentile) flow years.
- Action 3: Draft storage reservoirs to meet Lower Columbia summer flow and velocity equivalent objectives on a seasonal and weekly basis.
- Action 4: Operate reservoirs at rule curves and seek additional flow augmentation volumes from Snake River and Canadian reservoirs to better meet spring and summer flow and velocity objectives.

The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the 2008 FCRPS Biological Opinion and its 2010 Supplement to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the 2008 FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions that Oregon proposed in that litigation, including the items noted above; thus NMFS is not adopting as part of this recovery plan the additional actions proposed by Oregon.

In the Columbia River estuary, under the terms of the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a), the action agencies will implement an expanded estuary habitat program to address limiting factors that affect juvenile salmonids rearing in the estuary. These estuary habitat projects will increase the amount of juvenile salmonid shallow-water habitat and benefit all ESA-listed ESUs. The 2008 FCRPS Biological Opinion and its 2010 Supplement incorporate a relative survival improvement estimate of 9.0 percent for ocean-type ESUs (including Lower Columbia River fall Chinook and Columbia River chum salmon) to be derived from habitat improvements, and an estimate of 5.7 percent for stream-type ESUs (including Lower Columbia River coho salmon, spring Chinook salmon, and steelhead). In addition, the Biological Opinion projects that actions to reduce predation in the estuary will increase survival by additional amounts, as shown in Table 4-5.

**Table 4-5**
*Projected Survival Improvements for Lower Columbia Salmon and Steelhead from Actions to Reduce Predation in the Estuary*

| | Survival Improvement (%) |
|---|---|
| Coho salmon | 8.8 |
| Spring Chinook salmon | 3.1 |
| Fall Chinook salmon | 1.7 |
| Chum salmon | 1.0 |
| Steelhead | 4.4 |

Source: NMFS (2008f and 2010a).

As noted in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a), actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement that relate to estuarine habitat, predation, and flow are contributing to implementation of actions called for in the module; however, these Biological Opinion actions are projected to yield only a portion of the total survival improvements that the estuary module hypothesizes are possible in those categories. Thus, the module identifies habitat, predation, and flow actions that are larger in scope than the actions that are required under the 2008 FCRPS Biological Opinion and its 2010 Supplement.

For information on stratum-level hydropower strategies, see Sections 6.6.4, 7.4.3.4, 7.5.3.4, 7.6.3.2, 8.6.4, and 9.6.3.

## 4.4 Hatcheries

For more than a century, fish managers have used hatcheries in the Lower Columbia River to produce fish for harvest. Although some early hatchery programs supplemented already large naturally spawning populations, most were developed to compensate for declining numbers of naturally spawned salmon and steelhead, which were experiencing the detrimental effects of habitat loss (particularly related to hydropower dams) (LCFRB 2010a). Today, salmon and steelhead production in the lower Columbia region is dominated by hatchery-origin fish (ODFW 2010, LCFRB 2010a).

Although the actual number of artificial production programs changes annually based on funding and broodstock availability, in 2011 there were more than 80 separate artificial production programs in the lower Columbia region. Almost all of these programs produce fish for harvest; a few produce fish for reintroduction purposes or to supplement severely depressed natural populations. Most Lower Columbia programs produce either coho or Chinook salmon, while a smaller number produce steelhead, and four programs produce chum salmon (Turner, personal communication 2011).[14]

As shown in Table 4-6, artificial production programs release millions of fall Chinook salmon, spring Chinook salmon, coho salmon, chum salmon, and steelhead into lower Columbia River subbasins each year, although Lower Columbia production has been reduced substantially over the past 15 years. In addition to these releases, hatchery fish released elsewhere in the Columbia Basin migrate through the lower Columbia River as juveniles and adults.

**Table 4-6**
*Hatchery Releases of Salmon and Steelhead in the Lower Columbia River, 2011*

| LCR Release | By ODFW | By WDFW | By USFWS | Total |
|---|---|---|---|---|
| Fall Chinook* | 11,991,500 | 14,800,000 | 17,034,500 | 43,826,000 |
| Spring Chinook** | 1,225,000 | 2,940,400 | 1,714,000 | 5,879,400 |
| Coho | 5,404,000 | 6,689,000 | 643,900 | 12,746,900 |
| Summer Steelhead | 255,000 | 1,066,100 | 0 | 1,321,100 |
| Winter Steelhead | 510,000 | 1,234,300 | 111,500 | 1,855,800 |
| Chum | 0 | 307,000 | 0 | 307,000 |
| All releases | | | | 65,936,200 |

* Fall Chinook includes tules, upriver brights, and Select Area brights.

**Excludes Clackamas hatchery spring Chinook salmon, which are in the Upper Willamette spring Chinook ESU.

Source: Turner, personal communication (2011).

Annual returns of adult hatchery-origin fish are large relative to returns of adult fish produced naturally in the Columbia Basin. For example, from 2000 to 2010, the number of adult Lower Columbia River hatchery-origin fall Chinook salmon returning annually to the Columbia River ranged from 27,000 to 156,400, while natural-origin Lower Columbia River fall Chinook salmon returns numbered between 4,300 and 26,000 fish (Joint Columbia River Management Staff 2011). From 2000 to 2008, annual coho salmon returns ranged from 318,600 to more than 1.1 million, with almost all being hatchery-origin fish (NMFS 2008b).[15]

[14] Only three of these chum salmon hatchery programs are part of the ESU; NMFS has not yet evaluated the fourth, which the Oregon Department of Fish and Wildlife initiated in 2010, for inclusion in the ESU.

[15] Over this same time period, the geometric mean number of natural-origin spawners for the two largest coho salmon populations totaled less than 3,000 (http://www.nwfsc.noaa.gov/trt/trt_documents/lcolumbia_coho.pdf).

At the time many hatchery programs were developed, little was known about the impacts of hatchery fish on natural populations. Instead, it was generally believed that hatchery fish could be substituted for naturally spawning fish without lasting consequences; there was little understanding of the negative impacts hatchery fish could have on naturally spawning populations and of the need to protect naturally spawning populations and their habitats.

Today scientists and managers understand that hatchery programs have the potential both to benefit and to harm Lower Columbia River salmon and steelhead. The weight of available scientific evidence indicates that any artificial breeding and rearing will result in some degree of genetic change and fitness reduction in hatchery fish, and in the progeny of hatchery-origin fish that spawn naturally, relative to desired levels of diversity and productivity for natural populations. Hatchery fish thus pose a threat to the rebuilding and recovery of natural populations when they interbreed with fish from natural populations. That risk is outweighed in certain circumstances, such as when the near-term demographic risks of extinction outweigh longer term risks to population diversity and productivity. The extent and duration of genetic change and fitness loss and the near- and long-term implications and consequences for different species, for species with multiple life-history types, and under different hatchery practices and protocols remains unclear and should be the subject of further scientific investigation. NMFS believes that in certain circumstances, hatchery intervention is an appropriate tool to help avert salmon and steelhead extinction in the near term and to accelerate the recolonization of habitat. Otherwise, managers should limit interactions between hatchery- and natural-origin fish during the transition to hatchery practices consistent with recovery of listed populations, treaty fishing rights, and other applicable laws and policies.

### 4.4.1 Hatchery Limiting Factors and Threats

#### *4.4.1.1 Genetic Effects*

Hatchery practices such as broodstock collection and spawning protocols can cause genetic changes in hatchery fish. When hatchery-origin fish spawn with natural-origin fish, these genetic changes can be transmitted to the naturally produced fish; the larger the proportion of hatchery-origin spawners, the larger the genetic effects to the natural population. These genetic effects can be summarized as follows (NMFS 2011c):

- Loss of within-population diversity. Loss of within-population genetic diversity is a loss in the amount or type of genetic variability in a population, which can be caused by genetic drift and inbreeding depression. Genetic drift typically results from using small numbers of broodstock fish, having an unbalanced sex ratio in the broodstock, or pooling gametes from many adults during spawning. Inbreeding depression is a reduction in fitness caused by mating related individuals (Busack and Currens 1995, NMFS 2011c). The smaller the population, the higher the probability of inbreeding.

- Outbreeding effects. Outbreeding effects refer to changes in fitness and diversity caused by gene flow (i.e., interbreeding) in excess of natural rates among

genetically distinct populations (NMFS 2011c). One outbreeding effect is loss of within-population diversity, which may have no immediate impact on fitness. Large-scale loss of diversity is called "genetic swamping" or homogenization. The other outbreeding effect is outbreeding depression, in which changes in diversity caused by gene flow result in loss of fitness. Decreased disease resistance (Currens et al. 1997) and diminished ability to avoid predators (Tymchuk et al. 2007) are demonstrated results of outbreeding depression.

- Domestication selection. Domestication selection is intentional or inadvertent change to the natural selection regime caused by hatchery culture, resulting in the fish being less well adapted in the wild. Traits such as fish size, timing of spawning, growth rate, and feeding behaviors are subject to domestication selection. Domestication selection can also include the relaxation of selection. For example, hatchery fish do not participate in mate-choice behaviors, and the ability to perform these behaviors effectively can diminish in hatchery populations. When naturally produced fish interbreed with hatchery-origin fish, the level of domestication selection that occurs to the total population is a function of the fraction of hatchery-origin fish on the spawning grounds and the composition of the hatchery broodstock (NMFS 2011c, Berejikian and Ford 2004).

High proportions of hatchery fish on the spawning grounds have been common for decades in many Lower Columbia River salmon and steelhead populations, including the vast majority of Chinook and coho salmon populations. The impacts are likely a mix of outbreeding effects and domestication selection. For example, homogenization already has occurred in natural-origin coho salmon, which are now genetically indistinguishable from hatchery fish (Flagg et al. 1995). Fitness impacts from domestication selection are difficult to quantify in the Lower Columbia River, but a recent review of the literature worldwide suggests that progeny of hatchery fish that spawn in the wild are less likely to survive and return as adults than the progeny of natural-origin spawners (Berejikian and Ford 2004). In addition, Chilcote et al. (2011) found a negative relationship between the reproductive performance in natural, anadromous populations of steelhead, coho salmon, and Chinook salmon and the proportion of hatchery fish in the spawning population, including populations in the Lower Columbia.

#### *4.4.1.2 Competition (Density-Dependent Mortality) and Predation*

Density dependence refers to changes in the productivity of a population that are a result of the size of the population (productivity here refers to the number of returning offspring per spawner). In a density-dependent process, the number of offspring produced per spawner is higher when there are few spawners but decreases to one offspring per spawner (i.e., replacement) when the number of spawners is at the habitat's carrying capacity. With salmon and steelhead, density-dependent mortality can occur at any stage in the animal's life cycle and may be exacerbated by the introduction of large numbers of hatchery fish released over a relatively short time (NMFS 2011a).

Some scientists suspect that closely spaced releases of hatchery fish from Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the Columbia River estuary. NMFS (2011) and LCFRB (2010a) identified

competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged this uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

In addition, hatchery fish can sometimes prey directly on naturally produced juveniles, particularly chum salmon (ODFW 2010). Chum salmon fry from all populations may experience predation by hatchery-origin coho salmon, steelhead, and Chinook salmon smolts, although differences in life history patterns may moderate effects and the significance of interactions is unknown.

#### *4.4.1.3 Other Effects: Disease Transmission, Passage Blockages, Water Withdrawals, and Mixed Stock Harvest*

Hatchery fish can be infected with pathogens or parasites and have the potential to spread these organisms to natural-origin fish, although disease transmission from hatchery to natural-origin fish does not appear to be widespread in the lower Columbia region (LCFRB 2010a). (For more on this topic, see Section 4.6.1.3.) Hatchery structures, such as weirs, ladders, and screens, can injure fish and block or delay the passage of naturally produced adults and juveniles and thus reduce population spatial structure. Water withdrawals for hatchery operations can reduce tributary flow and habitat quality. Lastly, when hatchery production stimulates harvest, the incidental mortality of naturally produced fish can increase.

### 4.4.2 Regional Hatchery Strategy

For most Lower Columbia River ESUs, the general goals of the hatchery strategies developed by local recovery planners, and the basic approaches they recommend for achieving those goals, are similar. These goals and approaches are summarized below. Although these strategies are especially relevant for Lower Columbia River coho, spring and fall Chinook salmon, and Lower Columbia River steelhead (which have been subject to the most hatchery influence), they also are relevant to Columbia River chum salmon and late-fall Chinook salmon to the extent that hatcheries have created or may create limiting factors for these fish. Although the overall hatchery strategy will be applied consistently throughout the domain, management unit planners have or will establish specific targets for reductions in hatchery impacts at the population level and specific actions for achieving those targets; consequently, the specifics of how the regional hatchery strategy is applied will differ among populations and among hatchery programs.

The overall goals of the hatchery recovery strategies for the Lower Columbia ESUs are to (1) reduce hatchery impacts on natural-origin populations as appropriate for each population, (2) ensure that some populations have no in-subbasin hatchery releases and are isolated from stray out-of-subbasin hatchery fish, (3) use hatchery stocks in the short term for reintroduction or supplementation programs to restore naturally spawning populations in some watersheds, and (4) ensure rigorous monitoring and evaluation to

better understand existing population status and the effects of hatchery strategies on natural populations. The management unit plans include the additional societal goal of maintaining harvest opportunities created by hatchery fish. To accomplish these goals, hatchery programs will be managed in one of two general ways: as genetically integrated with or segregated from the natural populations they most directly influence.

In integrated programs, the intent is for the natural environment to drive the adaptation and fitness of a composite population of fish that spawns both in a hatchery and in the wild (i.e., to limit domestication). When hatcheries are used for conservation purposes (e.g., increasing the abundance of natural spawners, reintroducing fish into historically occupied habitats, or conserving genetic resources), integrated programs are the tool of choice because, by design, they allow a certain number of hatchery-origin fish to spawn in the wild. Integrated programs are also sometimes used to provide harvest opportunities, in which case the intent is to produce a desired set of fishery characteristics; however, there is still the need to reduce the effects of hatchery-origin fish spawning naturally. Integrated programs promote local adaptation and natural productivity through measures such as use of local broodstock, inclusion of naturally produced fish in the hatchery broodstock, and limits on the proportion of hatchery fish spawning in the wild.

In segregated programs, the intent is to maintain a hatchery population that is genetically isolated from and does not interact with the natural population. In contrast to integrated programs, segregated programs reduce domestication solely by minimizing spawning between natural-origin and hatchery-origin fish. The purpose of segregated programs is almost always to provide harvest opportunities. Risks posed to the natural population by the hatchery fish are reduced by minimizing interactions throughout the fishes' life cycles, including the proportion of hatchery-origin spawners (pHOS) on the spawning grounds. Managers control the proportion of hatchery-origin spawners through measures such as reducing overall production, shifting production to reduce straying into certain watersheds, changing production strategies to reduce straying (e.g., using different acclimation or release strategies), physically removing hatchery-origin fish (distinguishable by their clipped adipose fins) from natural spawning areas at weirs or other physical barriers, maintaining some wild fish sanctuaries (i.e., populations or substantial portions of subbasins where the pHOS target is very low), and improving habitat conditions to increase the number of natural-origin fish.

Theoretically the two approaches can be equally effective at limiting domestication impacts. Guidelines exist for applying both approaches to primary, contributing, and stabilizing populations (see Appendix A of Hatchery Scientific Review Group 2009.). The risks posed by a particular program are based not on the program type but on the gene flow levels involved (i.e., the proportion of natural-origin broodstock and the proportion of hatchery-origin spawners). Chilcote et al. (2011) evaluated the effects of hatchery programs on 89 steelhead, coho, and Chinook salmon populations and concluded that the proportion of hatchery-origin fish on the spawning grounds (pHOS) was negatively correlated with population productivity; furthermore, there seemed to be no difference in the impact of integrated and segregated programs on productivity. The authors concluded that, under most circumstances, ensuring that hatchery-origin fish are segregated from natural-origin fish on the spawning grounds (i.e., reducing pHOS)

may be the best long-term conservation strategy regardless of brood type. A note about Chilcote et al.'s integrated-segregated comparison is that integrated programs complying with modern gene flow guidelines for reducing domestication are still uncommon and typically quite new, so a more detailed assessment and finer scale research of truly integrated hatchery programs is needed.

In addition to managing potential genetic effects of hatchery-origin fish on natural-origin fish, another important management consideration for both integrated and segregated programs is potential ecological effects, such as competition for food or space between hatchery-origin and natural-origin fish. Therefore controlling pHOS and managing juvenile release levels to minimize detrimental interactions are important considerations in both integrated and segregated programs.

Collectively, both Oregon and Washington will use both segregated and integrated programs, for fishery enhancement and to help recover natural populations above tributary dams that have blocked access to historical habitat and in other areas where the abundance of natural-origin fish is very low and hatchery supplementation can reduce extinction risk in the short term. Managers will limit the proportion of hatchery-origin fish spawning naturally by using measures such as reducing overall production, changing production strategies to reduce straying (e.g., using different acclimation or release strategies), and physically removing hatchery-origin fish (distinguishable by their clipped adipose fins) from natural spawning areas at weirs or other physical barriers. Managing the genetic and ecological risks posed by hatchery fish with the demographic risks of low natural abundance and productivity is an important aspect of the strategy—one that is characterized by many uncertainties. Decisions about whether to use artificial propagation to help conserve populations must take into consideration the benefits to the population and ESU versus the risks.

In both states, efforts to reduce hatchery impacts will be targeted at achieving a level of hatchery influence appropriate to each population, based on its target status. For example, for populations targeted for a high probability of persistence, Oregon has established a target of no more than 10 percent hatchery-origin spawners in natural spawning areas (ODFW 2010). Washington will establish similar targets in the Conservation and Sustainable Fisheries Plan being developed by the Washington Department of Fish and Wildlife.

The management unit plans also call for continuing existing programs to mark all hatchery-produced coho salmon with an adipose fin clip and for coded wire tagging enough fish from each hatchery to allow identification of the hatchery program of origin (ODFW 2010). The latter strategy will allow rearing and release strategies to be modified where needed to further reduce straying. Another element of the hatchery strategy will be to continue best management practices such as juvenile release strategies that minimize impacts to natural populations.

There are critical uncertainties associated with the approaches described above. For integrated programs, the primary uncertainties include the availability of sufficient numbers of naturally produced fish for incorporation into the hatchery broodstock and the validity of assumptions concerning the natural fitness of hatchery-origin fish produced using natural broodstock. (For example, for a population with very low

natural-origin abundance, what are the tradeoffs of introducing natural-origin fish into hatchery broodstock versus waiting until natural production has increased?) For both integrated and segregated programs, a primary uncertainty concerns the effectiveness of measures such as weirs, acclimation, or release sites in achieving desired reductions in pHOS. A key unknown for all hatchery reforms is how quickly natural population diversity and productivity will respond to limiting the numbers of hatchery fish on the spawning grounds, and the extent to which limiting hatchery fish on the spawning grounds will affect the short-term demographic risks to the natural population by reducing the total number of spawners.

NMFS and other recovery planning entities will work with hatchery managers to develop more detail about how and when the strategies described above will be implemented, including detail about how strategies will reduce the proportion of hatchery fish in naturally spawning populations in a manner that addresses short-term demographic risks while promoting progress toward recovery objectives. A near-term priority is for state and federal hatchery program managers, working with NMFS and other recovery planning entities, to develop detailed schedules for implementation of hatchery strategies that address these questions and that lay out plans for transitioning from existing hatchery management to practices consistent with recovery of listed populations, treaty fishing rights, and other applicable laws and policies.[16] Through reduction of hatchery impacts, long-term priorities include achieving the recovery targets for each population and providing harvest opportunities.

NMFS expects that in general these "transition schedules" will reflect a plan to determine the extent to which naturally produced adults are returning to a population's habitat, as well as whether the intent for each population is to use hatchery supplementation. Use of hatchery supplementation should be considered an experimental strategy and not applied everywhere (that is, for some populations, the strategy should be to let the population restart based on stray spawners from nearby populations, an approach that has been demonstrated to work in the Scappoose and Clatskanie coho salmon populations). The schedules should also reflect an experimental design that will implement and evaluate several short-term recovery strategies to evaluate how different levels of natural and hatchery-origin fish on the spawning grounds affect progress toward recovery. The schedules should also address whether the long-term strategy for the use of hatchery fish is to isolate hatchery fish from the natural spawning population or to develop an integrated hatchery/natural population.

For information on stratum-level hatchery strategies, see Sections 6.6.6, 7.4.3.6, 7.5.3.6, 7.6.3.4, 8.6.6, and 9.6.5.

## 4.5 Harvest

Because of their wide-ranging migrations, anadromous salmonids are exposed to a variety of freshwater and ocean fisheries. Lower Columbia River salmonids are caught

[16] In 2011, hatchery managers developed transition schedules for Lower Columbia River fall Chinook populations designated in this recovery plan as primary (see "Task E" at http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Willamette-Lower-Columbia/LC/BO-tasks.cfm).

in commercial, recreational, and tribal fisheries along the West Coast of the United States and Canada as well as in the mainstem Columbia River and its tributaries. These various fisheries focus on different stocks and populations, taking fish to meet commercial, recreational, and tribal harvest allocations (see Table 4-7). A given fishery may be selective for fin-clipped hatchery fish or non-selective.

In the early part of the 20th century, nearly all commercial salmon fisheries in the Pacific Northwest operated in fresh water, where they harvested only mature salmon. Ocean fisheries became more important in the late 1950s as more restrictions were imposed on freshwater and coastal fisheries. Ocean harvest of salmon peaked in the 1970s and 1980s, after which commercial and recreational harvest of Columbia River salmon and steelhead declined. Harvest on Lower Columbia River tule fall Chinook salmon has been reduced from rates that averaged 69 percent during the years 1983 to 1993 (and that at one time exceeded 80 percent) to an average of 48 percent in the years since listing (NMFS 2008c). Tule fall Chinook salmon harvest rates recently have been further reduced, to 38 percent in 2009 and 2010 and 37 percent in 2011. Lower Columbia River spring Chinook salmon harvest averaged 51 percent during the years prior to listing (1980 to 1993) and has been reduced to around 20 percent since listing (NMFS 2008c). Harvest rates on Lower Columbia River coho salmon in the mid-1990s ranged from 75 to 90 percent, but since 2005, when NMFS listed this ESU, rates have averaged 16 percent. Before the mid-1970s, harvest impacts on Lower Columbia River steelhead were 70 percent or more. These impacts were reduced in 1975 when commercial harvest of steelhead in non-treaty fisheries was prohibited. Through implementation of mass marking and selective harvest, these rates were further reduced in the late 1980s and are now 10 percent or less. Columbia River chum salmon are not significantly affected by either direct or indirect harvest mortality (although historically harvest impacts were in the 90 percent range).

**Table 4-7**
*Fisheries Affecting Lower Columbia ESUs*

| Area | Fishery Type | Targeted LCR ESU |
|---|---|---|
| Canada, Southeast Alaska (ocean) | Commercial troll and net<br>Recreational fishing | Chinook (fall and spring)<br>Coho |
| U.S. West Coast (ocean) | Commercial troll<br>Treaty Indian commercial troll<br>Recreational | Chinook (fall and spring)<br>Coho |
| Lower Columbia River Mainstem | Commercial net; includes Select Area fisheries on fish returning to off-channel areas from net pen and hatchery releases in those places | Chinook (fall and spring)<br>Coho |
| Lower Columbia River Mainstem | Recreational; includes Select Areas | Chinook (fall and spring)<br>Coho<br>Steelhead |
| Columbia River Mainstem above Bonneville (Zone 6a) | Treaty Indian set net fishing, both commercial and ceremonial and subsistence<br>Recreational | Steelhead<br>Chinook (fall and spring) |
| Oregon and Washington Tributaries | Recreational | Steelhead<br>Coho<br>Chinook (fall and spring) |

Table 4-8 summarizes average harvest rates for natural- and hatchery-origin Lower Columbia River salmon and steelhead since the time of listing, along with the higher rates that generally occurred throughout the 1980s and early 1990s. Estimates of harvest impacts on a given ESU or run component can vary widely depending on the ESU, run component, and fisheries in question, the methods used, and the purpose of a given estimate. For example, estimates may be derived from coded-wire tags or through use of fishery models or other methods, depending on available information. Estimates may be for all fisheries or just those in the ocean or fresh water. In some cases, generalizations are sufficient to communicate the general magnitude of harvest impacts; in other cases, it is important to specify the source and methods used to derive a given estimate. The values in Table 4-8 rely where possible on published reports that contain specific estimates and explanations of how they were derived. These estimates may differ slightly from estimates in the management unit plans (which, in turn, may differ from each other). For purposes of indicating harvest impacts in general, all of these estimates are acceptable.

**Table 4-8**
*Recent (Since Listing) Estimated Harvest Rates on Lower Columbia River Salmon and Steelhead Compared to Historical Highs*

| Stock | Natural-origin Fish (% harvested) | Hatchery-origin Fish (% harvested) | Historical High (Natural-origin Fish) (% harvested) |
|---|---|---|---|
| Spring Chinook[1] | 20 | 34 | 51 |
| Fall Chinook (Tule)[2] | 48 | 48 | 69 |
| Fall Chinook (Bright)[3] | 36 | NA | 54 |
| Chum[4] | 1.6 | 1.6 | NA |
| Coho[5] | 16 | NA | 82 |
| Steelhead (winter)[6] | 4.1 | NA | 70 |
| Steelhead (summer)[7] | 6.7 | NA | 70 |

[1] 20 percent = average since listing (1999-2006), derived assuming that freshwater exploitation rates were 2 percent as a result of selective fisheries and constraints on upriver spring Chinook salmon); 34 percent = average since listing (1999-2006); 51 percent = average for the years 1980-1993 (NMFS 2008c).
[2] 48 percent = average since listing (1999-2006); 69 percent = average for the years 1983-1993 (NMFS 2008c).
[3] 36 percent = average since listing (1999-2006); 54 percent = average for the years 1979-1993 (NMFS 2008c).
[4] Source: NMFS 2008c. Although a specific estimate of historical harvest rates is not available, harvest on chum salmon was high through the 1950s but has been limited since the 1960s to a few hundred fish per year, at most (Washington Department of Fish and Wildlife and Oregon Department of Fish and Wildlife 2002).
[5] 16 percent = average since listing (2005-2007); 82 percent = average for the years 1970-1993 (NMFS 2008c).
[6] 4.1 percent = average for the years 2001-2007 (NMFS 2008c); 70 percent = generalization from LCFRB (2010a).
[7] 6.7 percent = average for the years 1998-2007 (NMFS 2008c); 70 percent = generalization from LCFRB (2010a).

Fisheries affecting Lower Columbia River salmon and steelhead are managed by a number of regional and international organizations and agreements, including the Pacific Salmon Commission (which implements the Pacific Salmon Treaty between the United States and Canada), the Pacific Fishery Management Council, state fishery regulations in Oregon and Washington, the Columbia River Compact, and management agreements negotiated between the parties to *U.S. v. Oregon*. In addition, federal statutes such as the ESA and Magnuson-Stevens Fisheries Conservation and Management Act influence harvest management decisions. Fishery managers continually review population abundance and marine survival conditions, and adjust harvest rates and timing to minimize impacts to natural-origin stocks. They generally try to manage fisheries using a combination of gear, timing, area, and mark-selective regulations to optimize the harvest of hatchery-origin fish and strong natural stocks and protect weaker natural-origin stocks. Because of these fishing regulations and other actions, harvest rates for hatchery-produced Chinook salmon, coho salmon, and steelhead are higher than for natural-origin fish of the same species.

Both the Oregon and Washington management unit plans provide detailed information on the fisheries that affect Lower Columbia River salmon and steelhead and the organizations, agreements, and statutes that guide harvest management decisions (see

LCFRB 2010a pp. 3-62 through 3-69 and 3-70 through 3-75 and ODFW 2010 pp. 91 and 94).

### 4.5.1 Harvest Limiting Factors and Threats

Harvest affects the viability of Lower Columbia River salmon and steelhead populations by causing mortality to naturally produced adult fish, influencing population traits, and reducing nutrients in freshwater ecosystems.

#### *4.5.1.1 Harvest Mortality*

Harvest mortality can be either direct or indirect. Direct harvest mortality is associated with fisheries that target specific stocks. This includes both single-stock (terminal) and mixed-stock (intercept) fisheries. Single-stock fisheries are the most effective method for targeting a specific stock and commonly occur in terminal harvest areas where one stock is known to be present. In mixed-stock fisheries, the management challenge is to harvest from mixed populations having various available surpluses (sometimes including populations with no surplus) as the populations move through the fishery area at various rates and abundances. Harvest of a specific stock in the mix can be achieved through management decisions (e.g., fishery openings that use time and area to target stocks when and where they are abundant relative to other stocks), fishery adaptations (e.g., gear designed to target specific stock/species), or fishery regulations (e.g., prohibitions against retaining certain species).

Indirect mortality includes mortality of fish harvested incidentally to the targeted species or stock, fish that die after being captured by fishing gear but not landed, and fish that die after being caught and released. Despite the various methods used to target a specific stock, incidental bycatch—the harvest of nontargeted stocks—still occurs, largely because various stocks intermingle. Most fisheries have specific reporting requirements and limits for incidental bycatch that are intended to lessen the harvest impacts to non-targeted stocks. For the Columbia River, federal, state, and tribal harvest managers set specific incidental harvest percentages for protected stocks and manage fisheries so as not to exceed these limits. They also employ catch and release regulations that allow anglers to retain hatchery-origin salmon and steelhead but require them to release natural-origin fish. Mortality occurs as a result of catch and release because fish experience injury and trauma when they are caught and released, though the degree to which this occurs varies depending on the gear, timing and location of the fishery, and angler knowledge and skill.

#### *4.5.1.2 Selection for Size, Age, Sex, Distribution, or Timing*

Harvest may selectively remove fish based on size, age, sex, distribution, or run timing, depending on the gear, timing, and location of the fishery. Such selection can affect the reproductive success, genetics, structure, and biodiversity of populations. Gear or run timing selectivity may influence population productivity by removing older, larger individuals, too many individuals of one sex, or the larger females carrying the most eggs. Fishing-influenced changes in the average sizes and ages of salmon populations have been well documented (Ricker 1981). Body size is related to redd digging success (Beacham and Murray 1987) and/or fecundity, and larger fish usually carry more eggs

(Sandercock 1991). When too many individuals with high reproductive potential are removed, the population's productivity is reduced. A fishery might also disproportionately harvest the early portion of a run because of market- or industry-driven needs, or because of the timing of hatchery fish runs. Run timing is heritable (Garrison and Rosentreter 1981), so when fish that run at a certain time are selectively removed, the run timing of the entire population can shift. There is evidence that this may have occurred in Lower Columbia River coho salmon, with hatchery practices being a contributing factor (Cramer and Cramer 1994). However, it is likely that the reductions in coho salmon harvest in recent years have addressed concerns regarding selective effects of harvest because selective pressure is proportional to the magnitude of harvest impact. (For information on harvest-related limiting factors and recovery strategies specific to coho salmon, see Sections 6.4.4 and 6.6.5, respectively.)

#### *4.5.1.3 Nutrient Supply and Carrying Capacity*

Adult salmon carcasses in streambeds promote primary production, and their flesh and eggs are directly consumed by aquatic insects (Wipfli et al. 1999) and rearing fish (Bilby et al. 1996). This creates a biological feedback loop that benefits future salmon production. The chronic depression of salmon biomass to freshwater ecosystems may be contributing to reduced carrying capacity for salmon (Cederholm et al. 1999, Knudsen 2002). By reducing the number of spawners, harvest plays a role in diminishing the amount of nutrients provided to the system.

### 4.5.2 Regional Harvest Strategy

As noted above and described in more detail in Chapters 6 through 9, harvest managers have implemented substantial reductions in harvest for Lower Columbia River Chinook salmon, coho salmon, and steelhead since around the time NMFS listed these species under the ESA. Local recovery planners believe that for spring Chinook salmon, steelhead, and chum salmon, current harvest impacts are generally consistent with long-term recovery goals, at least in the near term. For these species the management unit plans recommend ancillary and precautionary measures to ensure that harvest does not adversely affect conservation and recovery in the future. For spring Chinook salmon, the Washington management unit plan notes that in the near term, harvest rates may need to be lower in some years to reduce the risks of critically low escapements during poor ocean conditions and to protect local populations. For fall Chinook and coho salmon, efforts will focus on (1) refinements in harvest management (including abundance-based management) to reduce risk to naturally produced fish, and (2) continued review of overall harvest rates.

Although the harvest management requirements of each ESU are unique and must be addressed separately, the management unit recovery plans rely on several principles and general approaches that harvest managers will employ to address recovery needs related to harvest impacts on Lower Columbia River salmon and steelhead. In general, the harvest strategy focuses on refining harvest management and reducing impacts where needed so that the target status of each population can be attained within an acceptable time frame, while still maintaining harvest opportunities that target hatchery-produced fish.

To accomplish these overall objectives, the management unit plans call for the use of six general approaches as appropriate and feasible (see Chapters 6 through 9 for details):

- **Abundance-based harvest management**: In abundance-based harvest management, managers base annual harvest decisions on the predicted adult returns for that year. In some cases the management unit plans call for (1) refining the existing harvest matrix to ensure that it adequately accounts for weaker components of the ESU or reflects changes in natural production as recovery actions are implemented, or (2) developing methods to predict the abundance of natural-origin fish so that abundance-driven harvest principles can be effectively applied.

- **Weak stock management principles**: In using weak stock management principles, harvest managers consider the impact of harvest rates on the abundance and productivity of weaker populations or population groupings in the ESU. For fall Chinook salmon harvest management, until recently harvest rates were established based on an indicator stock that was relatively healthy, because it was one of the few for which data on natural-origin returns were available. In response to actions outlined in the management unit recovery plans, managers have been exploring ways to incorporate additional, and weaker, stocks into those used to evaluate harvest impacts on the ESU.

- **Mark-selective harvest:** By marking hatchery fish and focusing harvest on them, managers can maintain harvest opportunity and increase harvest of hatchery-origin fish while limiting impacts to natural-origin fish. The harvest recovery strategy includes actions to broaden the use of mark-selective fishing methods, including, in some cases, the development of new gear and methods for commercial fishing.

- **Filling information needs**: Filling information needs will allow harvest managers to make management decisions that better protect natural-origin fish. Needs include, for example, better information on natural-origin and hatchery-origin spawner escapement, better estimates of natural population productivity, and better estimates of catch-and-release mortality rates in commercial and recreational fisheries. For coho salmon, there is an additional need to improve estimates of harvest impacts for natural-origin fish in ocean and Columbia River mainstem fisheries, because of the complexities of coho salmon's protracted run timing and the mix of natural-origin and unmarked hatchery-origin fish.

- **Ancillary and precautionary actions:** For some species or runs (steelhead and chum salmon), recovery planners believe that current harvest impacts are generally consistent with long-term recovery goals, at least in the near term. For these species they recommend ancillary and precautionary measures to ensure that harvest does not adversely affect conservation and recovery in the future.

- **Adaptive management:** As recovery proceeds and populations that now have little natural production begin to exhibit appreciable natural production, the management unit plans note that managers will need to reevaluate the impacts

of harvest on the recovering populations and possibly readjust harvest management.

The management unit plans include the societal goal of maintaining harvest opportunities created by hatchery fish and have prioritized ESA recovery strategies that allow for continued harvest opportunities while working toward recovery; these strategies have been incorporated into the recovery plan. In addition, as part of their broad sense goals, the management unit plans envision eventual harvest of naturally produced salmon and steelhead from healthy, self-sustaining populations.[17]

In terms of recommended harvest rates, Oregon management unit planners did not recommend specific annual harvest rates; instead, in its analyses it used modeled, long-term average harvest rates for each species and assumed that harvest actions such as abundance-based, weak-stock management and mark-selective commercial fisheries would be implemented. The Washington management unit plan recommends a phased harvest strategy involving lower near-term rates to reduce population risks until habitat improvements are achieved. Modeling in the Washington management unit plan shows scenarios in which harvest rates would be managed for benchmarks in each of three 12-year implementation periods. The benchmark range is a target to be met within the designated period and to assess progress toward recovery. Generally the modeling projects that harvest rates eventually would increase as the benefits of other recovery actions were realized and natural production improved. These modeling results are planning targets and not predictions of future harvest rates; managers will establish future harvest rates based on observed indicators in Lower Columbia River salmon and steelhead populations.

In addition to these general approaches outlined above, NMFS will ensure that best available science continues to be used to determine harvest rates that, when combined with other threat reduction strategies, are likely to achieve positive growth rates and move populations to their target status over the long term. In ESA evaluations of hatchery and harvest actions, NMFS expects to analyze the combinations of effects of multiple actions when appropriate. For example, when harvest levels being evaluated are supported by hatchery production, the ecological, genetic, and other effects of hatchery production on both the juvenile and adult life stages also need to be considered as part of the harvest impact analysis.

## 4.6 Ecological Interactions

### 4.6.1 Limiting Factors and Threats Related to Ecological Interactions

Anthropogenic changes to habitat in the lower Columbia River region have altered the relationships between salmonids and other fish and wildlife species, leaving Lower Columbia River salmon and steelhead more vulnerable to predation by piscivorous fish,

[17] Currently, targeted harvest on naturally produced North Fork Lewis late-fall Chinook salmon is occurring when returns are above the escapement goal. The baseline persistence probability of this population, which has remained largely uninfluenced by hatchery production and has not experienced the population bottlenecks common among tule fall Chinook salmon populations, is estimated to be high.

birds, and pinnipeds (i.e., seals and sea lions) and subject to competition with introduced fish species and possibly hatchery-origin fish for limited food and habitat.

#### *4.6.1.1 Predation*

Significant numbers of salmon and steelhead are lost to fish, avian, and pinniped predators during migration and residency in the lower Columbia River and estuary (Northwest Power and Conservation Council 2004a). Although predation on salmon and steelhead has always occurred, predation rates in the lower Columbia River and estuary are believed to be higher now than they were historically because of anthropogenic changes in physical habitat that have increased predator abundance, predation effectiveness, or both. In addition, when hatchery-origin fish are present in large numbers, they can attract avian and fish predators of salmonids and spur predatory behavior that results in mortality of natural-origin juveniles. In the Columbia Basin this typically occurs at reservoir heads, at the face of dams, and at turbine spillway and bypass discharge areas (LCFRB 2010a). Researchers have also hypothesized that it is possible that a mass of hatchery-origin fish migrating through an area could also overwhelm predators, providing a beneficial, protective effect to co-occurring naturally produced fish (Fresh and Schroder 1987, Fritts and Pearsons 2008).

Dams, pile dikes, and other in-water structures in the lower Columbia River and estuary have created slack-water refuges and micro-habitats preferred by the northern pikeminnow, a native fish that feeds on juvenile salmonids. A bounty program on pikeminnow instituted in 1990 has reduced predation by 25 percent (Friesen and Ward 1999, NMFS 2000b). Still, pikeminnow in the lower Columbia mainstem have been estimated to consume up to 9.7 million juvenile salmon per year (Beamesderfer et al. 1996). Introduced fish such as walleye, smallmouth bass, and catfish also prey on juvenile salmonids in the estuary and mainstem, although in smaller numbers than pikeminnow; these warm-water species may benefit from the elevated water temperatures in Bonneville Reservoir and the Columbia River estuary.

Human alterations of the Columbia River estuary have contributed to increased predation by native birds, specifically Caspian terns, double-crested cormorants, and various gull species. Piscivorous birds congregate near dams and in the estuary around man-made islands and consume large numbers of emigrating juvenile salmon and steelhead (Roby et al. 1998). Populations of terns and cormorants in the estuary have increased significantly, in part because the deposition of dredged materials has created high-quality habitat for terns (Bottom et al. 2005). These habitats include Rice Island (at River Mile [RM] 21), which terns used for nesting from 1984 to 2000, and East Sand Island (RM 5), which has been an active nesting site since 1986. Double-crested cormorants are attracted to the estuary in part because of its tens of thousands of pilings, pile dikes, and other structures that provide perching opportunities. The loss of habitat elsewhere in the world has contributed to Caspian terns and double-crested cormorants relocating to the Columbia River estuary, which now has the world's largest nesting colonies of these species. In addition to being more numerous than they were historically, terns and cormorants in the estuary may be more effective in their predation because decreased fine sediment inputs to the estuary have reduced the turbidity that otherwise would help shield juvenile salmonids from predators.

The increased numbers of terns and cormorants have translated into measurable predation impacts on juvenile salmonids (Bonneville Power Administration, U.S. Bureau of Reclamation, and U.S. Army Corps of Engineers 2004). In 2006, Caspian terns and double-crested cormorants each were estimated to consume approximately 3.6 million juvenile salmon and steelhead (Collis and Roby 2006). How many of these juveniles are from the Lower Columbia River salmon ESU or steelhead DPS is unknown. However, evidence suggests that the steelhead DPS is likely to be affected by predation more than the other ESUs. Species-specific estimates of predation by Caspian terns from 1988 to 2000 were consistently highest for steelhead (9.4 to 12.7 percent), followed by coho salmon (3.6 to 4.1 percent), with the lowest rates observed in yearling Chinook salmon (1.6 to 2.9 percent) (Ryan et al. 2003).

Pinniped predation on adult spring Chinook salmon and winter steelhead in the Columbia River estuary continues to increase. On the West Coast, the total abundance of California sea lions is approximately 250,000; Stellar sea lions total about 31,000, and Pacific harbor seals total about 25,000 (Griffin 2006). Each spring about 1,000 Stellar sea lion males, 3,000 Pacific harbor seals, and 800 California sea lions take up residence in the lower estuary (Griffin 2006). Approximately 1,000 sea lions and harbor seals enter the freshwater portion of the estuary; of these, approximately 80 animals (primarily California sea lions) congregate at Bonneville Dam. The U.S. Army Corps of Engineers estimates that annual adult mortality at Bonneville Dam because of pinnipeds (primarily California sea lions) ranged from 0.4 percent (2002) to 4.2 percent (2007) during the study period ending in 2011 (U.S. Army Corps of Engineers 2011a).[18] Other, radio-telemetry-based studies suggest that annual pinniped predation on spring Chinook salmon and winter steelhead at Bonneville Dam may be as high as 8.5 percent and 20 percent, respectively (NMFS 2008c, Appendix G). There is a need for reliable estimates of the mortality caused by pinnipeds throughout the entire estuary and plume.

#### *4.6.1.2 Competition*

Habitat loss and alteration and releases of large numbers of hatchery fish have the potential to increase competition among salmonids and between salmonids and other fish species for food and habitat. In the case of salmon and steelhead, competition can occur in the tributaries, estuary, or ocean.

**Competition among Salmonids**

Competition is a natural process that helped shape the abundance of salmon and steelhead throughout their evolutionary history (Fresh 1997). The pressures of natural selection on salmon and steelhead promoted development of an array of life history strategies, involving differences in migration timing and habitat usage, so that populations could avoid competing for limited spatial and food resources (Quinn 2007, Naish et al. 2008) and, ultimately, maximize their marine survival.

At current levels of natural production it is unlikely that competition among salmonids is a limiting factor in the tributaries of the lower Columbia region. Even when hatchery

[18] Estimated consumption of adult salmonids ranged from a low of 1,010 in 2002 to a high of 6,081 in 2010; the percent of run consumed varied among reporting years in part because of changes in run size.

fish are released to tributaries in large numbers, releases usually are timed so that the juveniles are ready to migrate. It is more likely that competition between hatchery-origin fish and natural-origin fish is occurring in the Columbia River estuary, where food resources are limited and juvenile salmon and steelhead become concentrated on their way to the ocean (Fresh 1997).

Over the last century, habitat loss in the Columbia River estuary[19] has simplified Chinook salmon life history diversity there and concentrated the remaining salmon in more limited and fragmented regions (Bottom et al. 2005)—a process that may have increased competition. However, the impact of habitat loss on the Columbia River estuary's capacity to support juvenile salmon is unknown (Bottom et al. 2005).

Another unknown is the cumulative impact of hatchery-origin salmon and steelhead on natural-origin salmon and steelhead. When hatchery-origin fall Chinook subyearlings overlap spatially and temporally with natural-origin fall Chinook and chum salmon in the Columbia River estuary, they may compete directly for limited resources of food and space (Berejikian et al 2009), especially if the hatchery fish are released within a relatively short period or are larger than their naturally produced counterparts (NMFS 2011a, ODFW 2010). The competitive advantage that larger size or greater numbers imparts may result in so-called density-dependent mortality among Lower Columbia River salmon and steelhead (ODFW 2010) or compromise growth in natural-origin fall Chinook salmon juveniles, such that it takes longer to reach a critical size threshold above which mortality from predation will be reduced (Allee 2011). However, so little is known about the ecological interactions of hatchery- and natural-origin fish in the Columbia River estuary that it is difficult to conclude that competition for limited resources is occurring (Flagg et al. 2000). NMFS' Northwest Fisheries Science Center currently is investigating this topic. For more information see Appendix F.

**Competition between Salmonids and Other Species**

The new microdetritus-based food web in the estuary has benefited zooplanktivores, including American shad (*Alosa sapidissima*) (Sherwood et al. 1990). Shad were introduced to the Columbia River system in 1885, and their populations have grown substantially since then (Welander 1940, Lampman 1946), with up to 4 million adults returning to the estuary each year (Northwest Power and Conservation Council 2004a as cited in NMFS 2011a). The shad diet overlaps with that of subyearling salmonids in the Columbia River estuary, and juvenile shad and subyearling salmonids use similar heavily vegetated backwater habitats (McCabe et al. 1983). By their sheer numbers, shad represent a threat to trophic relationships in the Columbia River (NMFS 2011a). Other exotic fish species such as introduced walleye and catfish also have been able to capitalize on degraded conditions in the upper reaches of the estuary and altered food web dynamics through predation and competition for food resources (Northwest Power and Conservation Council 2004a).

[19] Diking and filling have reduced the surface area of the estuary by approximately 20 percent compared to historical levels, and approximately 43 percent of the tidal marshes and 77 percent of tidal swamps that existed in the Columbia River estuary before 1870 have been lost (Fresh 2005). In the Skagit River system in Washington, scientists have linked comparable habitat losses (i.e., 75 percent loss of tidal delta habitat) with density-dependent mortality of Skagit River fall Chinook (Beamer et al. 2005).

#### *4.6.1.3 Disease Transfer*

Salmon and steelhead can be infected by a variety of bacterial, viral, fungal, and microparasitic pathogens. Numerous diseases can result from pathogens that occur naturally in the wild or that may be transmitted to natural-origin fish via infected hatchery-origin fish. Disease transmission from hatchery-origin fish to natural-origin fish does not appear to be widespread in the lower Columbia region (LCFRB 2010a). To reduce the likelihood of disease transmission from hatchery salmonids to naturally produced fish, hatchery managers have established practices for monitoring fish health and sanitation and ensuring that hatchery fish are reared and released in healthy condition.[20]

### 4.6.2 Regional Ecological Interactions Strategy

The regional ecological interactions strategy involves reducing predation on all Lower Columbia River salmon and steelhead populations by redistributing Caspian terns and cormorants, increasing the pikeminnow bounty program in the Columbia River mainstem, and reducing marine mammal predation at Bonneville Dam using non-lethal or lethal measures. Managing predation by sea lions at Bonneville Dam is expected to benefit Gorge-stratum populations of Lower Columbia River salmon and steelhead ESUs. Pikeminnow are the focus of piscivorous predator reduction efforts because they are much more abundant in the region than introduced fish predators such as bass, walleye, and channel catfish (NMFS 2011a, LCFRB 2010a).

To reduce the risk of adverse ecological interactions between hatchery-origin and naturally produced salmon and steelhead, the Oregon and Washington management unit plans propose a combination of critical uncertainties research and near-term precautionary measures. Research needs include determining the degree of temporal and spatial overlap of hatchery- and natural-origin fish in the Columbia River estuary, the effect of competition on natural-origin fish, and the impact of predation of hatchery-origin fish on naturally produced fish. Near-term measures focus on restoring estuary habitat for fall Chinook and chum salmon and managing hatchery releases to minimize the risk of competition in the tributaries and Columbia River estuary (i.e., do not release hatchery-origin fish into the tributary rearing areas of natural-origin fish, coordinate releases to keep large numbers of hatchery-origin fish from accumulating in the estuary, and time releases so that hatchery-origin juveniles are at the optimal age and size to emigrate rapidly downstream and exit the estuary quickly, thus limiting interactions with natural-origin fish).

In addition, Allee (2011; see Appendix F) recommends research, modeling, and expert panel workshops to identify and evaluate potential methods of reducing the ecological interactions between hatchery-origin and natural-origin fish in the Columbia River estuary and thus lowering the risk of such interactions to natural-origin fish. These activities would focus on increasing scientific understanding of the habitat needs of hatchery-origin and natural-origin fish, habitats in the estuary, and risk to natural-origin

[20] For example, see Pacific Northwest Fish Health Protection Committee 1989, Integrated Hatchery Operations Team 1995, Washington Department of Fish and Wildlife 1996, Washington Department of Fish and Wildlife and Western Washington Treaty Indian Tribes 1998, U.S. Fish and Wildlife Service 1995, and U.S. Fish and Wildlife Service 2004.

fish in different habitats. Allee also supports recommendations by the Hatchery Scientific Review Group (HSRG) (2009) that would reduce the risk of negative cumulative impacts of hatchery-origin fish on naturally produced salmon and steelhead. For example, the HSRG recommends limiting hatchery production to the minimum needed to meet the systemwide harvest and conservation goals of the various managers, taking into account the carrying capacity of the mainstem, estuary and ocean; working with agencies and tribes to maximize survival of hatchery-origin fish consistent with conservation goals; and monitoring, evaluating, and adaptively managing hatchery programs to become more effective in meeting goals for conservation and harvest (Allee 2011).

### 4.6.3 Effects of Recovery Actions on Other Species

Recovery actions for listed Lower Columbia River salmon and steelhead have the potential to affect other species, both positively and negatively. These effects would most likely be manifested either through changes in habitat or through changes in predator/prey relations and interspecies competition resulting from shifts in the abundance and spatial distribution of LCR salmon and steelhead. In addition, one possible effect as salmon and steelhead recover and productivity improves is the increased delivery of marine-derived nutrients to inland ecosystems; these nutrients support other, non-salmonid species, including terrestrial species.

The species that share habitat or interact with LCR salmon and steelhead as predators or prey are numerous, as are the potential effects to those species from recovery actions. It is not possible to discuss them in detail in this plan. Nevertheless, in implementation, it will be useful and at times imperative to consider the effects of salmon recovery actions on other species. The National Environmental Policy Act requires federal agencies to evaluate such impacts for federal actions that significantly affect the environment. For species listed under the ESA, section 7(A)(2) of the ESA requires federal agencies to ensure that any actions they authorize, fund, or carry out are not likely to jeopardize the continued existence or adversely modify critical habitat of a listed species.

Generally, habitat-related recovery actions for Lower Columbia River salmon and steelhead would be likely to benefit many other species that share those habitats. For instance, the overall goals of the habitat recovery strategy to protect and restore functioning habitats and watershed processes are likely to benefit all native aquatic and riparian species, and it may be possible to specifically design protection and restoration projects in ways that benefit additional native species. For instance, culverts can be designed to pass not only salmon and steelhead but also lamprey, which do not have the jumping abilities of salmon and steelhead. Riparian habitat restoration projects can benefit not only aquatic but wildlife species, such as by providing micro-topographic features that would allow refuge from flooding.

Overall, NMFS expects that implementation of habitat protection and restoration actions for LCR salmon and steelhead would have concomitant benefits to many other native species and that adverse impacts would be rare. However, it is important that project developers consider such impacts. For example, dewatering of streams during instream restoration work can have adverse impacts on other aquatic species, and projects that create new equilibriums of species composition can shift predator/prey relationships in

ways that could be adverse to a species. It is especially important that, during implementation of this recovery plan, entities consider potential impacts of habitat projects on other federally or state protected species or species of concern. Design of recovery actions involving large-scale changes in habitat, such as actions to reduce Caspian tern and cormorant nesting habitat or large scale changes from freshwater to saltwater marsh habitat should consider impacts to target and non-target species.

A potential adverse impact of hatchery recovery actions on other species could occur through changes in numbers of hatchery fish produced. It is possible that hatchery production locally or throughout the Lower Columbia would be decreased as part of a recovery strategy. Although other recovery actions are aimed at increasing numbers of natural-origin salmon and steelhead, total salmon and steelhead production could be temporarily or permanently less than it is at present. Lower total production would mean less availability of salmon as predators or prey. In addition, the use of weirs at hatcheries to prevent hatchery-origin fish from spawning naturally could affect other species' habitat access.

Changes in harvest management could affect other species through shifts in predator/prey relationships and through impacts to species affected as bycatch in salmon fisheries. In addition, efforts to control predation on salmon by species such as marine mammals and birds could potentially affect the predator species.

Table 4-9 lists other federally listed aquatic species that could be affected by salmon recovery actions described in this plan. These species and the potential for salmon recovery actions to affect them are discussed briefly below.

**Table 4-9**
*Federally Listed Fish and Wildlife Species in the Lower Columbia Recovery Planning Area*

| Species | Range in Lower Columbia River Basin | Federal Listing Status | Type of Interaction with Salmon and Steelhead |
|---|---|---|---|
| Bull trout *(Salvelinus confluentus)* | Lewis and Clackamas subbasins, Lower Columbia River mainstem | Federally threatened | Predator of salmon and steelhead |
| Eulachon *(Thaleichthys pacificus)* | Lower Columbia River and tributaries | Southern DPS Federally threatened | Freshwater prey of salmon and steelhead |
| Green Sturgeon (*Acipenser medirostris*) | Columbia River estuary | Southern DPS Federally threatened | Bycatch in salmon fisheries |
| Southern resident killer whale | Occasionally forage on salmon in the mouth of the Columbia River | Federally endangered | Saltwater predator of salmon |
| Steller sea lion | Forage on salmon along lower Columbia River and estuary | Federally threatened | Predator of salmon |

Adapted from NMFS (2010c), Tables 3-9 and 3-29.

#### *4.6.3.1 Bull Trout*

Bull trout exhibit both resident and migratory forms and require complex habitat characterized by cold water and a variety of pools, riffles, water depths, and velocities. Bull trout occur from the Northwest Territories of Canada south to northern Nevada. Historically they were found in about 60 percent of the Columbia Basin, but their distribution and abundance in the basin have declined significantly (Natural Resources Conservation Service 2006, U.S. Fish and Wildlife Service 2010).

In 1999, bull trout were listed as a threatened species under the ESA (64 *Federal Register* 58909). Oregon has also listed them as a sensitive species. In 2002, the U.S. Fish and Wildlife Service published a draft recovery plan for bull trout. Twenty-two recovery units support bull trout listed in the Columbia Basin, three of which—the Willamette, Lower Columbia, and Hood River—overlap with the area addressed by this plan (U.S. Fish and Wildlife Service 1998, 2010).

Bull trout, salmon, and steelhead can occur in similar habitat types; however, bull trout are more sensitive than salmon and steelhead to increased water temperatures, poor water quality, habitat conditions, and low-flow conditions; thus, they more often occur in higher elevations with less disturbed habitats. Bull trout also require colder water temperatures than other salmon and trout, so they are more likely to occur in headwater streams where temperatures tend to be cooler. Because bull trout feed primarily on fish as subadults and adults, they can be a substantial predator of young salmon and steelhead. Juvenile bull trout feed on similar prey as salmon and steelhead (Natural Resources Conservation Service 2006; U.S. Fish and Wildlife Service 2008, 2010).

The primary interaction between bull trout and salmon and steelhead is that bull trout, as subadults and adults, prey on juvenile salmon and steelhead.[21] Overall changes in abundance of salmon and steelhead or bull trout could shift predator-prey relations. In addition, because bull trout use similar aquatic habitats as salmon and steelhead, the species can compete for food resources and space. In general, actions to protect and improve salmon habitat would also likely benefit bull trout.

#### *4.6.3.2 Eulachon*

The eulachon (also known as Columbia River smelt) is a small anadromous fish that occurs in the eastern North Pacific Ocean. Eulachon spend most of their lives in salt water but return to fresh water to spawn at 3 to 5 years of age. Juvenile eulachon rear in shallow to moderately deep nearshore marine areas. The Columbia River and its tributaries are believed to support the largest eulachon run in the world (NMFS 2008g). Eulachon regularly spawn in the mainstem Columbia River (up to Bonneville Dam), in Skamokawa Creek, and in the Cowlitz, Grays, Elochoman, Kalama, Lewis, and Sandy rivers (NMFS 2010b).

The southern eulachon DPS (i.e., populations spawning in rivers from the Nass River in British Columbia south to the Mad River in California) is listed as a threatened species under the ESA and is a Washington State species of concern.

Newly hatched and juvenile eulachon are a prey species for salmon and steelhead (although predation of eulachon by salmon and steelhead has not been cited as a reason for eulachon declines). In addition, spawned-out and decomposing eulachon contribute to the nutrient cycle of freshwater streams (NMFS 2010c).

#### *4.6.3.3 Green Sturgeon*

The green sturgeon is a long-lived, slow-growing anadromous fish that ranges from Alaska to Mexico. Juvenile green sturgeon rear and feed in both fresh and estuarine waters for 1 to 4 years before dispersing into marine waters. They spend 6 to 10 years at sea before returning to fresh water to spawn for the first time. Adults spawn multiple times and spend 2 to 4 years at sea between spawning events (71 *Federal Register* 17757). Green sturgeon feed on benthic invertebrates and small fish; salmon and steelhead have not been documented as part of their diet (NMFS 2005b and 2009b).

The southern green sturgeon DPS, which occurs in freshwater rivers and coastal estuaries and bays along the west coast of North America, including estuaries of Oregon and Washington and the lower Columbia River, is listed as a threatened species under the ESA (71 *Federal Register* 17757). The DPS aggregates in the Columbia River estuary and Washington estuaries in the late summer (NMFS 2009b).

Interactions among green sturgeon and salmon and steelhead are limited to the Columbia River estuary and Pacific Ocean marine waters. Green sturgeon are caught as bycatch in salmon and steelhead fisheries (NMFS 2009b).

[21] Bull trout also prey on other fish species (e.g., non-native trout); this may reduce predation by those species on juvenile salmon and steelhead.

#### *4.6.3.4 Southern Resident Killer Whale*

The southern resident killer whale stock has been observed in ocean waters of Washington and Oregon and near the mouth of the Columbia River during winter and early spring months (Ford et al. 2000, Wiles 2004, Zamon et al. 2007, NMFS 2008h, and NMFS 2008i). As of July 2011, the total estimated population of southern resident killer whales was 88 individuals (Center for Whale Research). Southern resident killer whales are ESA-listed as endangered and are also protected under the Marine Mammal Protection Act.

Southern resident killer whales consume a variety of fish and one species of squid, but salmon—Chinook salmon in particular—are their preferred prey (NMFS 2008i). Although the prey base of southern resident killer whales that forage near the mouth of the Columbia River is unknown, prey of southern resident killer whales that forage elsewhere in the Pacific Northwest has been recorded. Sampling in diet studies of southern resident killer whales has been conducted primarily during spring, summer, and fall months in inland waters off Washington and British Columbia (Ford and Ellis 2006, Hanson et al. 2007, and Hanson et al. 2010a). In inland waters from May to September, the southern residents' diet consists of a high percent of Chinook salmon, with on overall average of 88 percent of their diet consisting of Chinook salmon (Hanson et al. 2010a). Other salmonids eaten include steelhead (5 percent), coho salmon (3 percent), sockeye salmon (2 percent), and chum salmon (less than 1 percent). Ford and Ellis (2006) found that killer whales captured older (i.e., larger) than average Chinook salmon.

Other results indicated that, during fall months in inland waters, southern resident killer whales foraging within Puget Sound shift their diet to primarily chum salmon (Hanson et al. 2007). Although southern resident killer whales are thought to feed on salmon and steelhead year-round, their diet from January through April is poorly understood; during this period they range in ocean waters from British Columbia to central California (Krahn et al. 2002, Krahn et al. 2007, Ford and Ellis 2006, NMFS 2008h).

The preference of southern resident killer whales for Chinook salmon in inland waters, even when other species are more abundant, combined with information indicating that these whales consume salmon year-round, makes it reasonable to expect that southern resident killer whales prefer Chinook salmon when available in coastal waters. Sightings of resident killer whales off Westport, Washington, and in the mouth of the Columbia River may coincide with the spring Chinook salmon run in the Columbia River (Krahn et al. 2004, Zamon et al. 2007, NMFS 2008i). There are direct observations of two southern resident killer whale predation events in coastal waters; in both cases, the prey species was identified as Columbia River Chinook salmon (Hanson et al. 2010b). Chemical analyses also indicate the importance of salmon in the year-round diet of southern resident killer whales (Krahn et al. 2002; Krahn et al. 2007). Furthermore, Ford et al. (2009) found that southern resident killer whale survival rates correlated directly with the availability of Chinook salmon.

Based on recent estimates assuming a diet of only Chinook salmon, the southern resident killer whale stock requires, in total, approximately 289,000 to 347,000 Chinook salmon annually (Noren 2010), but the extent to which they depend on specific salmon

runs is not known. At different times of the year, southern resident killer whales may consume Chinook salmon that originate in the Fraser River, Puget Sound, Washington and Oregon coastal streams, the Columbia River, and central California streams (Hanson et al. 2010a), but data are insufficient to identify the proportion of different stocks in the year-round southern resident killer whale diet.

There is no evidence that southern resident killer whales distinguish between hatchery-origin and natural-origin salmon (Hanson et al. 2010a). Salmon production from Columbia River hatcheries may have partially compensated for declines in many natural-origin salmon populations to the benefit of resident killer whales (NMFS 2008i). The contribution of all salmon and steelhead from the Columbia Basin to the prey available to the whales in the ocean is substantial.

#### *4.6.3.5 Steller Sea Lion*

The eastern stock of Steller sea lions is resident year-round on the coasts of Oregon and Washington, and from the mouth of the Columbia River up to Bonneville Dam (NMFS 2008i and 2008c). No Steller sea lion rookeries (i.e., mating areas) exist near the Columbia River, but individuals use the South Jetty at the mouth of the river as a haul-out site year-round (Jeffries et al. 2000). Numbers vary seasonally, with peak counts of approximately 1,000 individuals during fall and winter months (NMFS 2008h). The eastern stock of Steller sea lions is listed as threatened under the ESA and is protected under Marine Mammal Protection Act.

Steller sea lions forage opportunistically on a wide variety of fishes in response to seasonal abundance. Foraging studies in the lower Columbia River and at Pacific Northwest coastal sites describe a variety of Steller sea lion prey species, including Pacific whiting, rockfish, eulachon, Pacific hake, anchovy, Pacific herring, staghorn sculpin, salmonids, octopus, and lamprey (Jeffries 1984, NMFS 2008c).

The extent to which eastern stock Steller sea lions depend on salmon in the lower Columbia River and nearby coastal waters is unknown, although some Steller sea lions exploit salmon at Bonneville Dam (NMFS 2008k). Salmon remains were found in 25 percent of the scat samples obtained in 2007 at Bonneville Dam. Surface observation at Bonneville Dam suggests that Steller sea lions in the Columbia River rely more on sturgeon than on salmon and steelhead (NMFS 2008h and 2008k and Stansell et al. 2011). However, predation by Steller sea lions on salmon elsewhere by (e.g., south Oregon coast) (NMFS 1997) appears to have increased since the 1980s and Steller sea lions have been observed preying on salmon smolts and adults (NMFS 1996).

## 4.7 Climate Change

### 4.7.1 Climate Change Limiting Factors and Threats

Likely changes in temperature, precipitation, wind patterns, ocean acidification, and sea level height have implications for survival of Lower Columbia River salmon and steelhead in their freshwater, estuarine, and marine habitats.

#### *4.7.1.1 Information Sources*

Recent descriptions of expected changes in Pacific Northwest climate that are relevant to listed salmon and steelhead include the U.S. Global Change Research Program's national climate change impacts assessment (Karl et al. 2009), the *Washington Climate Change Impacts Assessment* (Climate Impacts Group 2009), and the *Oregon Climate Change Assessment Report* (Oregon Climate Change Research Institute 2010).[22] These assessments are based on empirical observations and climate model projections. The regional climate assessments include projections from the Intergovernmental Panel on Climate Change's (IPCC) global climate models (Intergovernmental Panel on Climate Change 2007b), which were downscaled to reflect regional terrestrial and aquatic conditions (e.g., Salathe 2005) and ocean conditions (e.g., Stock et al. 2011). A new IPCC global climate assessment and a new national climate assessment, which will include updated analyses for the Pacific Northwest, are currently under way, with new climate projections expected by 2014.

Trends and projections of ocean acidification are reviewed in chapters of the Oregon and Washington climate assessments or subsequent publications of those chapters (Mote et al. 2010, Ruggiero et al. 2010, Huppert et al. 2009), based on primary research such as Feely et al. (2008).

Mote et al. (2008) and Ruggiero et al. (2010) described observed sea level height changes along the Pacific coast and reviewed literature projecting sea level changes in the Pacific Northwest. The West Coast Governors Alliance, along with the U.S. Geological Survey, NOAA, and the U.S. Army Corps of Engineers, have sponsored a study that the National Academies of Science will complete by 2013 that will provide sea level rise estimates for California, Oregon, and Washington for the years 2030, 2050, and 2100.[23] Various localized studies of projected sea level height changes are also available (e.g., Glick et al. 2007).

Recent reviews of the effects of climate change on the biology of salmon and steelhead in the Columbia Basin and the California Current region[24] include the Independent Scientific Advisory Board (ISAB) (2007a), the Oregon and Washington climate assessments (Huppert et al. 2009, Mantua et al. 2009 and 2010, and Hixon et al. 2010), NMFS (2010a), Ford (2011), and Crozier (2011). Crozier (2011, Section 9.3) includes a review of what is currently known regarding effects of ocean acidification on salmon and steelhead. In addition to these reviews, the NMFS Northwest Fisheries Science Center will be producing annual updates describing new information regarding effects of climate change relevant to salmon and steelhead as part of the FCRPS Adaptive Management Implementation Plan.

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[22] These documents are highlighted because they are recent comprehensive reviews of observed and expected climate change impacts in the United States and Pacific Northwest. Numerous other primary literature publications are available, many of which are cited in these reports. Additionally, NMFS annually reviews and summarizes scientific literature relevant to the effects of climate change on Pacific salmon and steelhead. The review of 2009 literature is included as Chapter 2.2.1 of NMFS (2010a); Crozier (2011) reviews 2010 literature.

[23] See http://www8.nationalacademies.org/cp/projectview.aspx?key=49290.

[24] The California current is a Pacific Ocean current that moves south along the western coast of North America, beginning off southern British Columbia and ending off southern Baja, California.

The following text summarizes expected climate change effects on listed Lower Columbia River salmon and steelhead, based on the above sources.

#### *4.7.1.2 Effects of Climate Change on LCR Salmon and Steelhead*

**Freshwater Environment**

Climate records show that the Pacific Northwest has warmed about 1.0 °C since 1900, or about 50 percent more than the global average warming over the same period. The warming rate for the Pacific Northwest over the next century is projected to be in the range of 0.1 to 0.6 °C per decade. Although total precipitation changes are predicted to be minor (+ 1 to 2 percent), increasing air temperature will alter snowpack, stream flow timing and volume, and water temperature in the Columbia Basin. Climate experts predict the following physical changes to rivers and streams in the basin:

- More precipitation falling as rain rather than snow (as a result of warmer temperatures)
- Diminished snowpack and alterations in stream flow volume and timing
- A trend toward loss of snowmelt-dominant and transient subbasins
- Continued increases in summer and fall water temperatures

More winter flooding is expected in transient and rainfall-dominated subbasins. Transient subbasins are those where stream flow is strongly influenced both by direct runoff from rainfall and by springtime snowmelt because surface temperatures in winter typically fluctuate around the freezing point. Over the course of a given winter, precipitation in transient subbasins frequently fluctuates between snow and rain, depending on relatively small changes in air temperature (Mantua et al. 2009).

Historically transient subbasins, such as those in which Gorge and some Cascade populations spawn and rear, will experience lower late-summer flows. For example, Figure 4-2 shows the expected patterns of stream flow in the White Salmon River, the Kalama River, and the Columbia River at Bonneville Dam in the 2020s, 2040s, and 2080s. The White Salmon River is a transient subbasin that currently exhibits a November-December peak hydrograph caused by rain and an April-May peak that is associated with melting snow. In future years the April-May snowmelt-driven peak is expected to be much lower or possibly nonexistent. As a more rainfall-driven river, the Kalama currently does not exhibit a distinct spring peak. Future flows are expected to increase in the winter and decrease in the spring, but the general rainfall-driven pattern will continue. The hydrograph for the mainstem Columbia River at Bonneville Dam is strongly influenced by spring snowmelt in Canada and the western Rocky Mountains. In the future, the spring freshet is expected to occur earlier, with fall and winter flows increasing and summer and early fall flows decreasing.

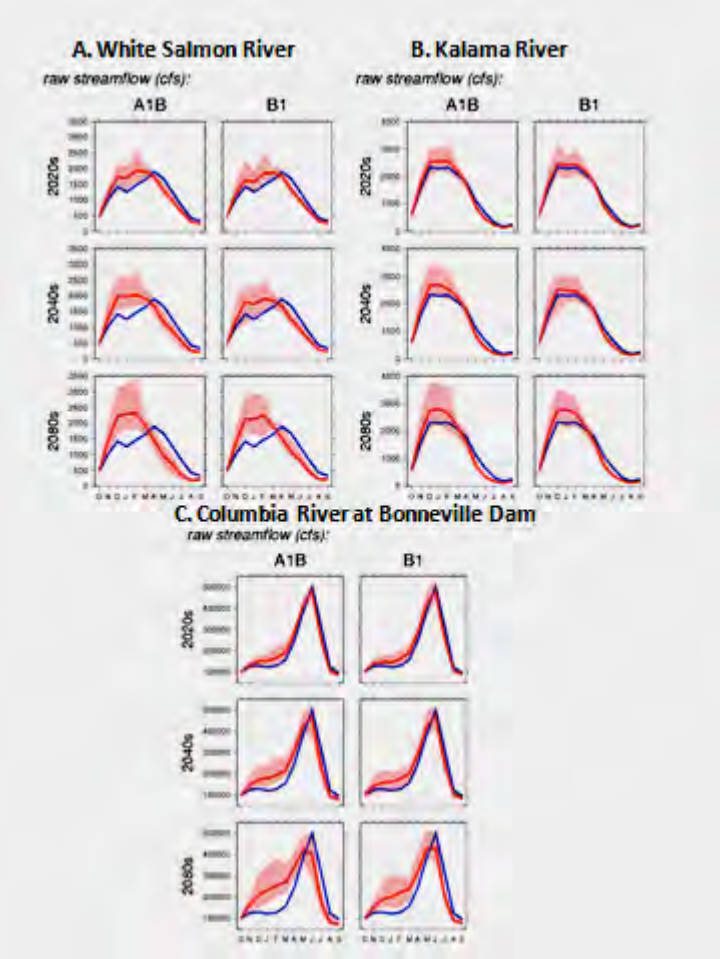


**Figure 4-2.** Projected Average Monthly Stream Flow (cfs) for the White Salmon and Kalama Rivers and the Mainstem Columbia River at Bonneville Dam[25]
(Note: Blue = historical average stream flow; red = projected stream flow for the 2020s, 2040s, and 2080s; shading = range of simulation results)

The predicted trend toward loss of snowmelt-dominant and transient subbasins will be most pronounced for some Gorge and Cascade subbasins with high-elevation headwaters that currently experience a spring freshet from melting snow. The hydrographs of most subbasins in the Lower Columbia domain are currently rainfall-dominated and will continue to be so as climate changes (Figure 4-3).

[25] Projections are made under two IPCC (2007) anthropogenic aerosol and greenhouse gas emission scenarios: A1B corresponds to "moderate" and B1 corresponds to "low" emissions during the 21st century (Stock et al. 2011). Figures are from the University of Washington Climate Impacts Group and are available at: http://www.hydro.washington.edu/2860/products/sites.

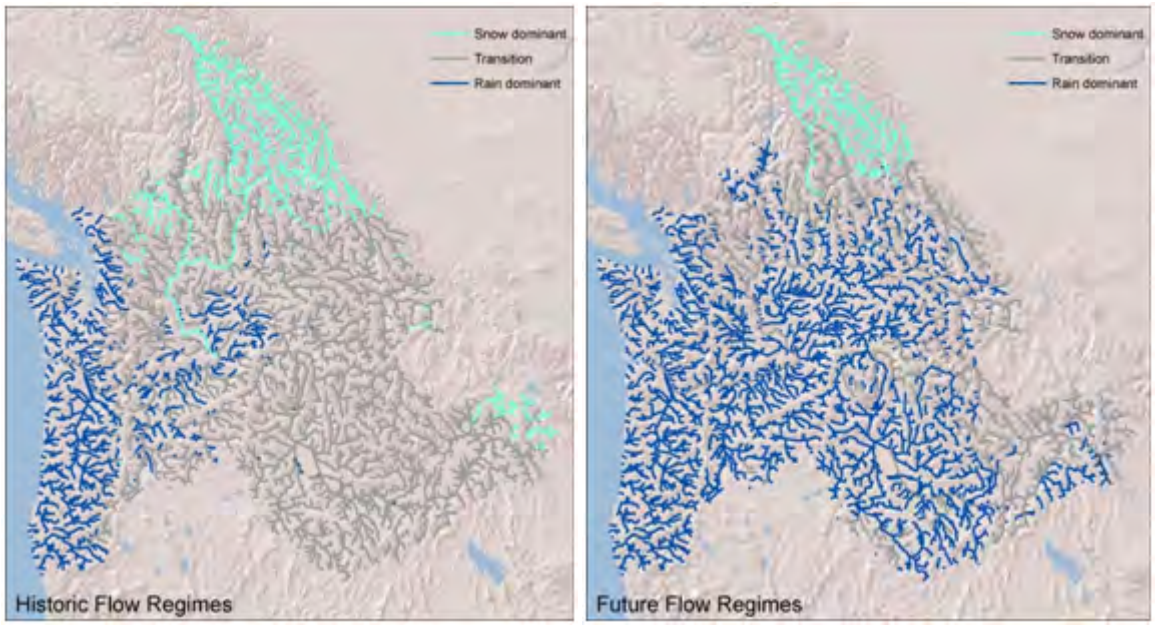


**Figure 4-3.** *Preliminary Maps of Predicted Hydrologic Regime for 1970-1999 and 2070-2099*[26]
Source: University of Washington Climate Impacts Group (www.hydro.washington.edu/2860/).

In the state of Washington, summer and fall water temperatures will continue to rise, with an increase of less than 1 °C expected by the 2020s but an increase of 2 to 8 °C predicted by the 2080s. By the 2080s, the number of Washington subbasins with a maximum weekly water temperature that exceeds 21.5 °C is expected to double, and thermal barriers greater than 21 °C are expected to increase in duration from 1 to 5 weeks in the 1980s to 10 to 12 weeks in the 2080s.

The changes in air temperatures, river temperatures, and river flows in the Pacific Northwest are expected to cause changes in salmon and steelhead distribution, behavior, growth, and survival. Although the magnitude and timing of these changes currently are poorly understood and specific effects are likely to vary among populations, the following effects on listed salmon and steelhead in fresh water are likely:

- Winter flooding in transient and rainfall-dominated subbasins may scour redds, reducing egg survival.
- Warmer water temperatures during incubation may result in earlier fry emergence, which could be either beneficial or detrimental, depending on location and prey availability.
- Reduced summer and fall flows may reduce the quality and quantity of juvenile rearing habitat, strand fish, or make fish more susceptible to predation and disease.

[26] Uses emission scenario A1B and global climate model CGCM3.1(T47), based on classification of annual hydrographs as in Beechie et al. (2006).

- Reduced flows and higher temperatures in late summer and fall may decrease parr-smolt survival.

- Warmer temperatures will increase metabolism, which may either increase or decrease juvenile growth rates and survival, depending on availability of food.

- Overwintering survival may be reduced if increased flooding reduces suitable habitat.

- Timing of smolt migration may be altered such that there is a mismatch with ocean conditions and predators.

- Higher temperatures during adult migration may lead to increased mortality or reduced spawning success as a result of lethal temperatures, delay, increased fallback for Gorge populations at Bonneville Dam, or increased susceptibility to disease and pathogens.

The degree to which phenotypic or genetic adaptations may partially offset these effects is being studied but currently is poorly understood.

**Estuarine Environment**

Climate change will also affect salmon and steelhead in the estuarine and marine environments. Effects of climate change on salmon and steelhead in estuaries include the following:

- Warmer waters in shallow rearing habitat may alter growth, disease susceptibility, and direct lethal or sublethal effects.

- Higher winter freshwater flows and higher sea level elevation may increase sediment deposition and wave damage, possibly reducing the quality of rearing habitat.

- Lower freshwater flows in late spring and summer may lead to upstream extension of the salt wedge, possibly influencing the distribution of salmonid prey and predators.

- Increased temperature of freshwater inflows and seasonal expansion of freshwater habitats may extend the range of non-native, warm-water species that are normally found only in fresh water.

In all of these cases, the specific effects on salmon and steelhead abundance, productivity, spatial distribution and diversity are poorly understood.

**Marine Environment**

Effects of climate change in marine environments include increased ocean temperature, increased stratification of the water column, changes in the intensity and timing of coastal upwelling, and ocean acidification. Hypotheses differ regarding whether coastal upwelling will decrease or intensify, but even if it intensifies, the increased stratification

of the water column may reduce the ability of upwelling to bring nutrient-rich water to the surface. There are also indications in climate models that future conditions in the North Pacific region will trend toward conditions that are typical of the warm phases of the Pacific Decadal Oscillation, but the models in general do not reliably reproduce the oscillation patterns. Hypoxic conditions observed along the continental shelf in recent years appear to be related to shifts in upwelling and wind patterns that may be related to climate change.

Climate-related changes in the marine environment are expected to alter primary and secondary productivity, the structure of marine communities, and, in turn, the growth, productivity, survival, and migrations of salmonids, although the degree of impact on listed salmonids currently is poorly understood. A mismatch between earlier smolt migrations (because of earlier peak spring freshwater flows and decreased incubation period) and altered upwelling may reduce marine survival rates. Ocean warming also may change migration patterns, increasing distances to feeding areas.

In addition, rising atmospheric carbon dioxide concentrations drive changes in seawater chemistry, increasing the acidification of seawater and thus reducing the availability of carbonate for shell-forming invertebrates, including some that are prey items for juvenile salmonids. This process of acidification is under way, has been well documented along the Pacific coast of the United States, and is predicted to accelerate with increasing greenhouse gas emissions.

Ocean acidification has the potential to reduce survival of many marine organisms, including salmon and steelhead. However, because there is currently a paucity of research directly related to the effects of ocean acidification on salmon and steelhead and their prey, potential effects are uncertain. Laboratory studies on salmonid prey taxa have generally indicated negative effects of increased acidification, but how this translates to the population dynamics of salmonid prey and the survival of salmon and steelhead is uncertain. Modeling studies that explore the ecological impacts of ocean acidification and other impacts of climate change concluded that salmon landings in the Pacific Northwest and Alaska are likely to be reduced.

**Summary of Likely Impacts of Climate Change**

NMFS' 2010 5-year status report for salmon and steelhead in the Pacific Northwest (Ford 2011) includes a summary of likely effects of climate changes on Pacific Northwest salmon and steelhead. Table 4-10, which is reproduced from Table 79 of Ford (2011), summarizes the main climate change effects and indicates the certainty of their occurrence and their expected magnitude. Table 4-10 addresses all listed salmon and steelhead in the Pacific Northwest, so some effects, such as some terrestrial climate effects on forest and riparian structure, are more relevant to interior Columbia Basin species. Ford (2011) point out that we need to consider the cumulative impacts of climate change across the salmon life cycle and across multiple generations. Because these climate effects are multiplicative across the life cycle and across generations, small effects at individual life stages can result in large changes in the overall dynamics of populations. This means that the mostly negative effects predicted for individual life history stages will most likely result in a substantially negative overall effect of climate change on Pacific Northwest salmonids over the next few decades.

**Table 4-10**
*Summary of Expected Climate Effects on Pacific Northwest ESUs*

| Habitat | Physical Change | Processes Affecting Salmon | Effect on Pacific Northwest Salmonid ESUs | Certainty |
|---|---|---|---|---|
| Terrestrial | Warmer, drier summers | Increased fires, increased tree stress, and disease will affect large woody debris, sediment supplies, and riparian zone structure | - - to 0<br>Largest effects likely to be felt in Interior Columbia populations, particularly in areas at lower and middle elevations | Low |
| | Reduced snowpack, warmer winters | Increased growth of higher elevation forests will affect large woody debris, sediment processes, and riparian zone structure | 0 to + | Low |
| Freshwater | Reduced summer flow | Less accessible summer rearing habitat | - - to -<br>Effects most pronounced in areas that currently have low flow, particularly in Interior Columbia populations | Moderate |
| | Earlier peak flow | Potential migration timing mismatch | -- to 0<br>Largest effects in “transition” areas that move from a snowmelt-dominated hydrograph to a rain-driven hydrograph | Moderate |
| | Increased floods | Redd disruption, juvenile displacement, upstream migration | - - to 0<br>Largest effects in “transition” areas that move from a snowmelt-dominated hydrograph to a rain-driven hydrograph | Moderate |
| | Higher stream temperature | Thermal stress, restricted habitat availability, increased susceptibility to disease and parasites | - - to -<br>Largest effects likely to occur in what currently are high-temperature areas of the Interior Columbia and low-elevation areas | Moderate |

| Habitat | Physical Change | Processes Affecting Salmon | Effect on Pacific Northwest Salmonid ESUs | Certainty |
|---|---|---|---|---|
| Estuarine | Higher sea level | Reduced availability of wetland habitats | -- to -<br>Largest effects on ESUs with a life history highly dependent on relatively long-term rearing in estuarine and tidally influenced areas | High |
| | Higher water temperature | Thermal stress and increased susceptibility to disease and parasites | - - to –<br>Largest effects on ESUs with highly estuarine-dependent life cycles and ESUs subject to stress at earlier life stages | Moderate |
| | Combined effects | Changing estuarine ecosystem composition and structure | - - to + | Low |
| Marine | Higher ocean temperature | Thermal stress, shifts in migration, susceptibility to disease and parasites | - - to -<br>Effects likely to vary by ESU, depending on ocean distribution | Moderate |
| | Intensified upwelling | Increased nutrients (food supply), coastal cooling, and ecosystem shifts; increased offshore transport | 0 to ++<br>Effects likely to vary by ESU and correspondence of outmigration with upwelling patterns | Moderate |
| | Delayed spring transition | Food timing mismatch with outmigrants, ecosystem shifts | - - to 0<br>Effects likely to vary by ESU depending on correspondence of outmigration with upwelling patterns | Moderate |
| | Increased acidity | Disruption of food supply, ecosystem shifts | - - to -<br>Effects likely to vary by ESU, dependent upon age and size at outmigration and ocean distribution | Moderate |
| | Combined effects | Changing composition and structure of ecosystem, changing food supply and predation | - - to +<br>Effects likely to vary by ESU depending on age and size at outmigration and ocean distribution | Low |

Effect ratings are: + +, strongly positive; +, positive; 0, neutral; -, negative, - -, strongly negative. Certainty level combines the certainty of the physical change with the certainty of the effect.

Source: Table 79 of Ford (2011); Table 79 was adapted from Stout et al. (2010) and includes citations for the main sources of information relied on for each entry.

## 4.7.2 Regional Climate Change Strategy

### *4.7.2.1 Mitigation Strategy*

The IPCC (Intergovernmental Panel on Climate Change 2007b) defines climate change mitigation as implementing policies and technological changes to reduce greenhouse gas (GHG) emissions and enhance greenhouse gas sinks. Reduction of greenhouse gas emissions is the most reliable solution to the adverse effects of climate change on listed Lower Columbia River salmon and steelhead over the long term. The climate change mitigation strategy for this recovery plan is for relevant entities to implement greenhouse gas reduction strategies. Possible mechanisms for doing so include the West Coast Governors' Global Warming Initiative (http://www.ef.org/westcoastclimate/) and the Oregon Global Warming Commission's recommendations (Oregon Department of Energy 2009). There is also a need to integrate these local strategies with mitigation strategies at larger spatial scales.

### *4.7.2.2 Adaptation Strategy*

The IPCC (Intergovernmental Panel on Climate Change 2007c) defines climate change adaptation as adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation strategies that contain measures to reduce impacts of climate change on Pacific Northwest salmon and steelhead include the Northwest Power and Conservation Council's Independent Scientific Advisory Board (2007a) review, the interim *Washington State Integrated Climate Change Response Strategy* (Washington Department of Ecology 2011), the *Oregon Climate Change Adaptation Framework* (Oregon Department of Land Conservation and Development 2010), and the draft *National Fish, Wildlife, and Plants Climate Adaptation Strategy* (U.S. Fish and Wildlife Service et al. 2012).

These adaptation plans commonly include the following general elements:

- Conserve adequate habitat to support healthy fish populations and ecosystem functions in a changing climate.
- Manage species and habitats to protect ecosystem functions in a changing climate.
- Reduce stresses not caused by climate change.
- Support adaptive management through integrated observation and monitoring and improved decision support tools.

The ISAB's recommendations for incorporating climate change considerations into restoration and recovery planning and recommended actions for reducing climate change impacts on Columbia Basin salmon and steelhead are specifically targeted to salmon and steelhead populations in the Pacific Northwest (Independent Scientific Advisory Board 2007a). NMFS incorporates the ISAB's recommendations by reference into this recovery plan, including those displayed in Table 4-11, some of which have been slightly modified to specifically apply to recovery of Lower Columbia River species. The management unit plans contain actions that implement many of these

strategies. There will be a need throughout implementation for additional evaluation of the extent to which the management unit plan actions have been tailored specifically to address climate change impacts in the Lower Columbia.

A number of the strategies in Table 4-11 are currently being implemented through the 2008 FCRPS Biological Opinion and its 2010 Supplement, the Northwest Power and Conservation Council's Fish and Wildlife Program, local recovery plans, and activities and research of other federal and non-federal agencies.

In addition, the management unit plans and estuary recovery plan module (NMFS 2011) identify climate change as a threat, incorporate general approaches to climate change, and present specific actions that are responsive to the general strategies outlined above.[27] Some of these actions overlap with tributary habitat actions or, in the case of the Oregon management unit plan, actions to reduce the impacts of human population growth. The following actions from ODFW (2010) are representative of management unit plan actions to reduce the impacts of climate change on salmon and steelhead:

- Develop recommendations for land management scenarios that address hydrograph changes that are due to climate change, impervious surfaces, and other factors that result in altered water runoff.

- Protect and restore riparian areas to improve water quality, provide long-term supplies of large wood to streams, and reduce impacts that alter other natural processes.

- Develop a methodology to assess and identify, and then protect, stream reaches and population strongholds that will be resilient/resistant to climate change impacts.

- Protect and restore headwater rivers and streams (salmon- and non-salmon-bearing) to protect the sources of cool, clean water and normative hydrologic conditions.

- Conduct a detailed climate change risk analysis for all populations and use this to help prioritize actions, or develop new ones, that are contained in the implementation schedule.

- Implement credible, science-based programs, policies, and rules that contribute collectively to protect fish and water resources.

These actions are examples only. For more information, see Table 7-3A of ODFW (2010) and p. 5-70 of LCFRB (2010a).

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[27] In calculating target abundances, Oregon recovery planners included an additional 20 percent "buffer" to account for the impacts of future threats—both climate change and human population growth—and expect that targets and actions will be adjusted as more specific information on the impacts of climate change becomes available. Washington recovery planners did not incorporate the impact of climate change or human population growth into its calculations of target abundances. NMFS' view is that this difference in approach is not significant for the reasons explained in Section 5.2.2.

**Table 4-11**
*Strategies and Representative Actions to Address Climate Change Impacts*

| Category | Strategy | Representative Actions |
|---|---|---|
| Planning Actions | Assess potential climate change impacts in each subbasin and develop a strategy to address these concerns as part of updates to subbasin and recovery plan. NMFS will help provide technical assistance to planners to help ensure that climate change is addressed thoroughly and consistently in subbasin and recovery plans. | |
| | Ensure that subbasin and recovery planners are aware of pertinent resources. As needed, NMFS and other entities will direct planners to tools and climate change projections that will aid them in assessing the subbasin impacts of climate change. Resources currently include:<br>• Pacific Northwest Climate Impacts Consortium: http://pnwclimate.org/<br>• Northwest Climate Science Center: http://www.doi.gov/csc/northwest/index.cfm<br>• University of Washington Climate Impacts Group: http://cses.washington.edu/cig/<br>• Oregon State University's Oregon Climate Change Research Institute: http://occri.net/<br>• NOAA's climate sciences program: http://www.climate.gov/<br>• North Pacific Landscape Conservation Cooperative: http://www.fws.gov/pacific/Climatechange/nplcc/ | |
| | Establish reserves through the purchase of land or conservation easements in locations likely to be sensitive to climate change that have high ecological value. Landscape-scale considerations will be critical in the choice of reserve sites because habitat fragmentation and changes of habitat will influence the ability of such reserves to support particular biota in the future. (Independent Scientific Advisory Board 2007a summarizes some generally accepted guidelines for selection of reserves or protected areas that are specifically intended to preserve biodiversity in the face of changing climate.) | |
| Tributary Habitat | Minimize temperature increases in tributaries by implementing measures to retain shade along stream channels and augment summer flow | • Protect or restore riparian buffers, particularly in headwater tributaries that function as thermal refugia<br>• Remove barriers to fish passage into thermal refugia |
| | Manage water withdrawals to maintain as high a summer flow as possible to help alleviate both elevated temperatures and low stream flows during summer and autumn | • Buy or lease water rights<br>• Increase efficiency of diversions |

| Category | Strategy | Representative Actions |
|---|---|---|
| | Protect and restore wetlands, floodplains, or other landscape features that store water to provide some mitigation for declining summer flow | • Identify cool-water refugia (subbasins with extensive groundwater reservoirs)<br>• Protect these groundwater systems and restore them where possible<br>• May include tributaries functioning as cool-water refugia along the mainstem Columbia where migrating adults congregate<br>• Maintain hydrological connectivity from headwaters to sea |
| Mainstem and Estuary Habitat | Reduce temperatures and create thermal refugia | • Remove dikes to open backwater, slough, and other off-channel habitat, thus increasing flow through these areas and encouraging increased hyporheic flow |
| Mainstem and Tributary Hydropower | Augment flow from cool or cold-water storage reservoirs to reduce water temperatures, or create cool-water refugia in mainstem reservoirs and the estuary | • Investigate increasing storage in existing reservoirs or adding new storage facilities,, but must be cautious with this strategy<br>• Investigate the possibility of implementing a seasonal flow strategy that includes cool-water releases from storage reservoirs in Lower Columbia River tributaries in late summer |
| | Use methods to increase surface passage of juveniles at Bonneville and The Dalles dams to move fish quickly through warm forebays and past predators in the forebays. | • Use corner collector at Bonneville Dam |
| | Reduce water temperatures in adult fish ladders at Bonneville and The Dalles dams | • Use water drawn from lower cool strata of forebay<br>• Cover ladders to provide shade |
| | Reduce the impact of higher fish predation rates caused by warming water temperature by reducing predator populations | • Reduce predation by introduced piscivorous species (e.g., smallmouth bass, walleye, and channel fish) in mainstem reservoirs and the estuary |
| Harvest | When setting annual quotas and harvest limits, conduct and use assessments that take into consideration the changing climate | • Reduce harvest during favorable climate conditions to allow stocks that are consistently below sustainable levels during poor phase ocean conditions to recover their numbers and recolonize areas of freshwater habitat<br>• Use stock identification to target hatchery stocks or robust wild stocks, especially when ocean conditions are not favorable |
| Hatcheries | Reduce density-dependent interactions among hatchery- and natural-origin fish; such interactions can cause lower growth and survival at times when climate effects reduce ocean productivity | • Control juvenile migration by reducing hatchery releases or modifying release timing to reduce competition and ensure that ocean entry coincides with favorable ocean conditions<br>• Consider changing systemwide habitat conditions in determining appropriate stocks for reintroduction programs |

## 4.8 Human Population Growth

### 4.8.1 Limiting Factors and Threats Related to Human Population Growth

An estimated 5 million people live in the Columbia Basin, and the human population in the region is expected to increase significantly in coming years. By the end of the twenty-first century, between 40 million and 100 million people are predicted to be living in the Columbia Basin (National Research Council 2004). Some communities—both urban and rural—can expect their populations to double between 2000 and 2020; significant growth also is projected for unincorporated areas. In Oregon, particularly fast growth is predicted in Clackamas, Clatsop, Columbia, Hood River, and Multnomah counties—areas that support Lower Columbia River coho, Chinook, and steelhead and Columbia River chum salmon. The population of these counties is expected to increase by 41 percent from 2003 to 2040 (State of Oregon Office of Economic Analysis 2004). In Washington, the populations of Clark and Cowlitz counties are projected to grow by 65 and 53 percent, respectively, from 2000 to 2030 (Washington State Department of Transportation).

The Oregon management unit plan describes in general the expected future impacts of human population growth on Columbia Basin fish and wildlife populations, based on work by the Independent Scientific Advisory Board (ISAB) for the Northwest Power and Conservation Council, Columbia River Basin Indian tribes, and NMFS (Independent Scientific Advisory Board 2007b). The ISAB reached the following conclusions:

- Population growth will increase the demand for water, land, and forests that are key to fish and wildlife populations. This demand for resources will increase threats to and extinction risks for fish and wildlife.

- Changes in land use related primarily to increases in human population size and per-capita consumption rates will increase water use, affect land management and, ultimately, affect fish and wildlife habitat.

- Increased demand for residential land is accelerating the rate of conversion of forest and agricultural lands.

- The dominant ongoing pattern of settlement in the Columbia Basin is exurban sprawl—i.e., the building of new communities on the fringes of urban growth boundaries. Exurban sprawl causes loss, degradation, and fragmentation of habitat and increases infrastructure costs, social conflict, and harmful interactions among people and wildlife.

- Urbanization will increase the amount of impervious surfaces (pavement, roofs etc.) in watersheds, increasing surface runoff during storm events and reducing groundwater recharge and thus base flows.

- The effects of population growth will combine with those of climate change to increase pressure on fish and wildlife habitats.

- Demands for fresh water from surface and groundwater will increase. Climate change-related decreases in the snowpack at higher elevations will exacerbate this situation, especially during low-flow summer and fall seasons.

- Population-related factors external to the Columbia Basin, such as international trade, shipping, dredging, hazardous material transport, and airborne pollution, will affect fish and wildlife habitat in the basin. (See ODFW 2010, and Independent Scientific Advisory Board 2007b.)

### 4.8.2 Regional Strategy for Human Population Growth

The Oregon and White Salmon management unit plans identified both human population growth and climate change as future threats to lower Columbia salmon and steelhead. Although Oregon recovery planners believe that actions should be implemented now to prevent or mitigate for the future impacts of these threats (ODFW 2010), the magnitude of the impacts is unknown. Given this uncertainty, in developing improvement targets for Oregon populations, recovery planners added an additional 20 percent in abundance above that needed to achieve the WLC TRT criteria for stratum viability. This 20 percent conservation "buffer" is intended as a precautionary measure, to help mitigate for the impacts of both human population growth and climate change in the interim until the magnitude of these threats is better understood. Once the impacts of human population growth and climate change can be estimated more accurately, targets and actions in the Oregon management unit plan can be adjusted accordingly (ODFW 2010).

The Washington management unit plan did not identify future growth in the human population as a threat to lower Columbia salmonids or incorporate the impacts of future threats—either population growth or climate change—in its calculations of target abundance for recovery of its populations. Instead, managers and scientists expect to use the adaptive management process to refine strategies, measures, and actions as the Washington management unit plan is implemented, based on the observed response to initial recovery efforts. Effective adaptive management will require that initial actions be of a magnitude sufficient to produce a measurable response, and that monitoring be sufficient to detect a response (LCFRB 2010a).

All three management unit plans include actions or strategies that will lessen the impacts of human population growth. The Oregon management unit plan identifies specific actions as mitigation for this threat, while the Washington management unit plan incorporates mitigation measures into larger scale principles and strategies that are intended to address six major categories of threats to lower Columbia salmon and steelhead. Representative actions and strategies from the Oregon and Washington management unit plans are shown in Table 4-12. The White Salmon management unit plan includes broader scale strategies that, although not linked specifically to human population growth, will help mitigate this threat; examples include protecting the highest quality habitats through acquisition and conservation, conserving rare and unique functioning habitats, consistently applying best management practices and existing laws to protect and conserve natural ecological processes, and providing public outreach to educate river uses and others (NMFS 2011).

**Table 4-12**
*Representative Actions and Strategies to Mitigate for Human Population Growth*

| Oregon Management Unit Plan | Washington Management Unit Plan |
|---|---|
| • Prevent impacts from future development in the 100-year floodplain—i.e., impacts on wetlands and vegetation, stormwater effects, and the net impacts of new dikes, levees, and floodwalls. Mechanisms to prevent impacts in the 100-year floodplain include updating floodplain maps and incorporating them into land use planning, providing FEMA funding for land acquisition in the floodplain, developing new regulations, and enhancing efforts to enforce existing land use regulations, laws, and ordinances.<br>• Encourage the Oregon Division of State Lands to (1) require avoidance and minimization of impacts to waters of the state in priority areas identified in the Oregon management unit plan, (2) work with landowners to design projects that avoid and minimize impacts to wetlands and other waters of the state, (3) explore opportunities to target compensatory mitigation towards areas that have high intrinsic potential for salmon and/or have been identified as priority areas for restoration, and (4) explore conservation easements for state-owned lands with high value for salmon recovery.<br>• Protect existing high-quality or intact habitat, including riparian areas and off-channel habitat in the Columbia River estuary; actively purchase off-channel estuarine habitats in urban and rural settings.<br>• Encourage and provide incentives for local, state, and federal regulatory entities to maintain, improve, and enforce habitat protections throughout the lower Columbia region.<br>• Provide more resources and incentives to small (non-metropolitan) communities so they have the infrastructure to better manage runoff from impervious surfaces.<br>• Educate landowners about the benefits of protecting and stewarding intact ecosystems and the costs of degraded systems.<br>• Remove or modify over-water structures to provide beneficial habitats.<br>• Reduce the stranding of juvenile salmonids on estuarine beaches as a result of ship wakes.<br>• Reduce salmonid exposure to toxic contaminants: implement pesticide and fertilizer best management practices; identify and reduce industrial, commercial, and public sources of pollutants; and restore or mitigate contaminated sites in the Columbia River estuary.<br>• Implement stormwater best management practices in cities and towns. | • Consider salmon recovery needs up front in the comprehensive land use planning process, along with other social, infrastructure, and service needs.<br>• Protect habitat conditions and watershed functions through land use planning that guides population growth and development—i.e., plan growth and development to avoid sensitive areas (wetlands, riparian zones, floodplains, unstable geology, etc.), encourage the use of low-impact development methods and materials, and apply mitigation measures to offset potential impacts<br>• Protect and restore instream flows through water rights closures, purchase or lease of existing water rights, relinquishment of existing unused water rights, enforcement of water withdrawal regulations, and implementation of water conservation, use efficiency, and water re-use measures to decrease consumption.<br>• Protect and restore runoff processes, in part by limiting additional watershed imperviousness, managing stormwater runoff, and protecting and restoring wetlands in developed and developing areas.<br>• Protect and restore water quality, in part by reducing fecal coliform bacteria levels and inputs of chemical contaminants from developed lands. This involves managing industrial point sources of pollution, eliminating urban and rural sewage discharge to streams, and treating storm runoff before it is discharged to streams.<br>• Manage recreation to protect and restore sensitive areas, such as by rehabilitating damaged terrain, limiting use, and managing human waste.<br>• Maintain and/or establish adequate resources, priorities, regulatory frameworks, and coordination mechanisms for effective enforcement of land and water use regulations for the protection and restoration of habitats significant to fish and wildlife resources. This involves establishing cooperative enforcement partnerships among agencies, public, land owners, and industry and establishing priorities to emphasize protection in key areas and facilities where recovery efforts are focused. |

For more detail on mitigating for the growing human population in the Columbia Basin, see the Oregon and Washington management unit plants (ODFW 2010 pp. 100-101, 226-239; LCFRB 2010a Chapter 5, S.S10, S.M1, S.M3, S.M12, S.M13, S.M15, and 2.M16).

## 4.9 Summary

No single factor, threat, or threat category accounts for the declines in the species addressed in this recovery plan; instead, the status of Lower Columbia River salmon and steelhead and Columbia River chum salmon is the result of the cumulative impact of multiple limiting factors and threats. Although this chapter and the recovery analyses that follow highlight major recovery topics, factors, and actions, recovery of the Lower Columbia species will be accomplished through improvements in every general threat category. Even small increments of improvement will play an important role. When the need for improvement for most ESUs is so large, the contribution of no population or threat reduction can be discounted.

# 5. Overall Approach to Species Recovery Analyses

This chapter describes the management unit recovery planners' overall analytical approach to species recovery and summarizes the key analyses that formed the basis of their recovery strategies. Where relevant, the chapter describes differences in approaches and discusses the implications of those differences. For more detailed information on these methodologies, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013). The chapters that follow describe the results of these analyses as applied to each Lower Columbia River ESU or DPS.

In general, the management unit recovery planners did the following:

1. Evaluated the baseline status of their respective populations using techniques based on those recommended by the WLC TRT (McElhany et al. 2003, McElhany et al. 2004, McElhany et al. 2006) and demonstrated in McElhany et al. (2007).[1]

2. Identified limiting factors for each Lower Columbia River salmon and steelhead population.

3. For each population, quantified the estimated baseline impacts of six categories of threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and ecological interactions or predation—that were useful as an organizing construct for grouping limiting factors.

4. Established a target status for each population, taking into consideration (1) each population's potential for improvement, in view of available habitat and historical production, (2) the degree of improvement needed in each stratum to meet WLC TRT guidelines for a viable ESU, and (3) for some ESUs, the desire to accommodate objectives such as maintaining opportunities to harvest hatchery-origin fish. Management unit recovery planners used the term "conservation gap" to refer to the difference between the baseline and target status for each population.

5. Calculated the population-specific improvements in abundance and productivity and, in some cases, spatial structure and diversity that would be needed to achieve each population's target status (i.e., to close the conservation gap).[2]

6. Identified a "threat reduction scenario" for each population, meaning a specific combination of reductions in threats that would lead to that population achieving its target status.

[1] McElhany et al. (2007) was a collaborative effort by NMFS Northwest Fisheries Science Center staff, ODFW staff, and a consultant working for the Lower Columbia Fish Recovery Board to refine the approach to population status assessment.

[2] The Oregon management unit plan contains explicit targets for spatial structure and diversity; in the Washington management unit plan, spatial structure and diversity improvements are implicit in the abundance and productivity targets.

7. Identified and scaled recovery strategies and actions to reduce threats by the targeted amount in each category. Management unit planners identified recovery strategies and actions through meetings and workshops with stakeholders, including representatives of implementing and affected entities.

8. Considered the probable effects of actions, established benchmarks for implementation, and identified critical uncertainties and research, monitoring, and evaluation needs for each species for incorporation into an adaptive management framework (see Chapter 10 of this plan).

9. Developed implementation frameworks that address organizational structures, prioritization methods, systems for tracking implementation, coordination needs and approaches, and stakeholder involvement (see Chapter 11of this plan).

The following text further describes the analytical framework used by the management unit recovery planners.

## 5.1 Baseline Population Status

Management unit recovery planners assessed each population's status based on methods described in technical reports developed by the WLC TRT and demonstrated in McElhany et al. (2007). (For a description of these reports, see Section 2.5.2). For each population, management unit recovery planners evaluated and scored the four VSP attributes of productivity/abundance, spatial structure, and diversity individually and then integrated the VSP attribute scores to yield an overall population score; this overall score reflects the population's baseline probability of persistence, as shown in Table 5-1. For information on specific benchmarks and scoring techniques, see McElhany et al. (2003, 2004, 2006, and 2007, primarily the latter two documents), pp. 50 through 75 of ODFW (2010), and pp. 4-11 through 4-18 of LCFRB (2010a).

Readers should note that in the management unit plans, Oregon described its populations in terms of extinction risk, while Washington described its populations in terms of persistence probability. This is a difference in terminology only, as persistence probability is simply the inverse of extinction risk status (e.g., high persistence probability is the equivalent of low extinction risk, as shown in Table 5-1). This ESU-level plan presents the status of all populations in terms of persistence probability (this is consistent with the language of the WLC TRT technical documents) but uses "extinction risk" in some contexts when that term is more illuminating.

**Table 5-1**
*Population Scores and Corresponding Probability of Persistence (or Extinction)*

| Score* | Probability of Persistence** | Population Status | Probability of Extinction ** | Extinction Risk |
|---|---|---|---|---|
| 0 | 0 – 40% | Very low (VL) | 60 – 100% | Extinct or at very high risk of extinction (VH) |
| 1 | 40 – 75% | Low (L) | 25 – 60% | Relatively high risk of extinction (H) |
| 2 | 75 – 95% | Medium (M) | 5 – 25% | Moderate risk of extinction (M) |
| 3 | 95 – 99% | High (H) | 1 – 5% | Low/negligible risk of extinction (L) |
| 4 | > 99% | Very high (VH) | < 1% | Very low risk of extinction (VL) |

* Population scores between whole numbers are rounded. For example, a score of 2.75 would be rounded up to 3; a score of 2.45 would be rounded down to 2.

** Probability over a 100-year time frame.

Source: McElhany et al. (2006).

### 5.1.1 Oregon Approach to Assessing Baseline Status

Oregon recovery planners established a "baseline period" from which to assess population status based on the most recent data available at the time of their assessment—generally up through 2006-2008 for modeling of abundance and productivity and through 2004 for assessment of other VSP parameters and threat assessments (ODFW 2010).

Consistent with the WLC TRT's approach (described in McElhany et al. 2003 and 2006 and demonstrated in McElhany et al. 2007), the four VSP parameters of productivity/abundance, spatial structure, and diversity were the foundation of the status assessment for Oregon populations. Oregon recovery planners also used the WLC TRT's scoring method—i.e., total score = 2/3 A&P + 1/6 spatial + 1/6 diversity (see McElhany et al. 2007)—to derive a composite score for each population. As in McElhany et al. (2007), Oregon recovery planners based scoring of the abundance/productivity attribute on population viability modeling and used a mix of quantitative and qualitative metrics to score the spatial structure and diversity attributes.

To reflect the uncertainty associated with both the data and the assessment methods, and consistent with McElhany et al. (2007), Oregon recovery planners presented results as a distribution of possible extinction risk scores, displayed graphically as a diamond shape (see Figure 5-1), rather than as a single score. The widest point of the diamond reflects the most likely extinction risk category, while the upper and lower points correspond to the extremes of possible extinction risk values. The height of the diamond represents the degree of uncertainty about the assessment. During later steps in their recovery analyses, Oregon recovery planners used the extinction risk category at the diamond's widest point as the baseline extinction risk.

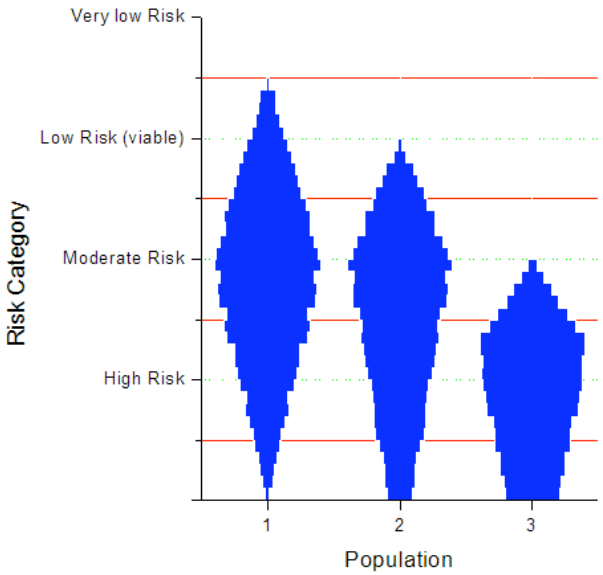


**Figure 5-1.** *Sample "Diamond Graph" Showing Populations with Different Distributions of Extinction Risk (Inverse of Persistence Probability*)

### 5.1.2 Washington Approach to Assessing Baseline Status

Washington recovery planners evaluated population status circa 1999—around the time when most Lower Columbia River salmon and steelhead were listed under the ESA (LCFRB 2010a)—and did not use time series information after the baseline period in any quantitative analysis; they considered spatial structure and diversity conditions as of 1999). The Washington recovery planners chose this point because it ensures that the baseline assessments reflect the conditions that led to the initial ESA listings and that must be addressed through recovery actions.

As in Oregon, the four VSP parameters of productivity/abundance, spatial structure, and diversity were the foundation of the Washington status assessments. However, instead of deriving an overall population score using the WLC TRT's formula (total population status score = 2/3 A&P + 1/6 spatial structure + 1/6 diversity), Washington recovery planners assessed population status by (1) scoring the abundance/productivity, diversity, and spatial structure attributes for each population (see Table 4-4 in LCFRB 2010a) and then (2) designating the lowest of the individual attribute scores as the overall population status. The Washington recovery planners considered this "lowest attribute" approach intuitively simpler, less subjective, and more effective in capturing spatial structure and diversity concerns.

A consultant to the Lower Columbia Fish Recovery Board developed abundance/productivity scores for each Washington population using a quantitative population viability analysis that uses a stochastic stock-recruitment model. This approach is similar to the risk analyses in McElhany et al. (2007) and the Oregon management unit plan. Scores for spatial structure and diversity that go into the overall population status scores were based on qualitative analyses and expert judgment using

criteria established by a technical work group and based on guidance established by the WLC TRT (McElhany et al. 2003).

The Washington management unit plan notes that there is significant uncertainty in the population status assessments—on the order of at least one point in the population score. The uncertainty is a consequence of the limited data and limited understanding of the relationships between population attributes and persistence probability (LCFRB 2010a).

### 5.1.3 White Salmon Approach to Assessing Baseline Status

For baseline population status, the White Salmon recovery planners used status assessments completed by the WLC TRT in 2004 (McElhany et al. 2004), the most current assessment of the White Salmon populations available at the time of plan development. The 2004 evaluation involved individual WLC TRT members ranking the VSP attributes based on best available information and professional judgment and providing an estimate of "data quality" based on their assessment of the overall amount of information available for each attribute. Overall population viability was determined using the WLC TRT's formula for a weighted average of the VSP attributes (McElhany et al. 2004).

### 5.1.4 Differences in Status Assessment Methods

The population assessment methods used by Oregon, Washington, and White Salmon recovery planners were similar to each other and consistent with the approach outlined in McElhany et al. (2000), but they differed in specific application, such as selection of the baseline period and integration of VSP attribute scores to yield an overall population score (see Table 5-2). As a result, the status assessments in the different plans are not necessarily directly comparable. However, the actual results of the assessments are generally in agreement on the relatively poor status of most populations. This suggests that the fundamental similarities of the approaches outweigh their differences, which appear to have relatively little effect on overall conclusions about population status. NMFS' view is that the status assessment methods used by the WLC TRT, McElhany et al. (2007), and the management unit plans all are scientifically sound, are based on the best information available, and provide a credible assessment of population status and a solid foundation for additional assessments and identification of initial recovery actions.

As described in more detail in Section 5.10, NMFS is required to complete reviews of the status of listed salmon and steelhead every 5 years. The most recent reviews, which were completed in 2011, used the same VSP concept that the management unit planners used and reached conclusions about population status similar to those in the management unit plans (76 *Federal Register* 50448). As new methods for status assessment are developed and new and better data become available, NMFS will employ the improved techniques in future 5-year reviews and recovery plan updates.

**Table 5-2**
*Key Differences in Status Assessment Methodologies*

| Element | Oregon | Washington | White Salmon |
|---|---|---|---|
| Baseline period | Modeled baseline abundance assuming environmental conditions similar to those through 2006-2008 | Used circa 1999 (i.e., ESA listing dates) as the baseline period | Used 2004 as the baseline period |
| Population score | Used weighted average of VSP attribute scores to determine population score | Used lowest VSP attribute score to determine population score | Used weighted average of VSP attribute scores,* tempered by professional judgment |
| Uncertainty | Expressed uncertainty graphically, using diamond shapes and reduced extinction risk thresholds to account for uncertainty | Stated that population score may be off by one or more points | Scored the quality of the data for each VSP attribute |

* McElhany et al. (2004), which was the source of the status assessments for the White Salmon populations, used a slightly different list of VSP attributes than did the Oregon and Washington recovery planners—namely, productivity, juvenile outmigrants, diversity, habitat, and spatial structure. The WLC TRT later refined the VSP parameters to abundance, productivity, spatial structure, and diversity.

## 5.2 Target Status

### 5.2.1 Recovery Scenario

Through an iterative process, management unit recovery planners collaborated to reach agreement on a target status for each population that either was consistent with the WLC TRT's stratum and ESU/DPS viability criteria or that would contribute to comparable ESU/DPS risk levels. Where a population's target status was inconsistent with the WLC TRT's stratum or ESU/DPS criteria, the management unit plans documented the basis for the divergence. In this ESU-level recovery plan and the management unit plans, the target viability statuses are referred to collectively as the "recovery scenario" for the ESU or DPS (see Table 3-1 for the actual scenarios). Recovery planners also designated each population as "primary," "contributing," or "stabilizing" to reflect its expected level of contribution to recovery of the ESU or DPS (see Section 3.1.3 for a description of these designations).

### 5.2.2 Conservation Gaps

The difference between a population's baseline status and its target status reflects the magnitude of improvement needed to close the "conservation gap." Oregon and Washington management unit recovery planners estimated the abundance, productivity, spatial structure, and diversity improvements that would be necessary for each population to achieve its target status.[3] They quantified gaps in abundance and

[3] Washington management unit recovery planners quantified the conservation gap for the White Salmon populations as part of their conservation gap analysis (see LCFRB 2010a). The White Salmon management unit plan (NMFS 2013) does not include this gap analysis. Instead, the plan presents a baseline status for

productivity using the same stochastic population viability analysis models used to estimate baseline risk status and treated gaps in spatial structure and diversity qualitatively because of a lack of rigorous quantitative analytical methods and criteria for these parameters.[4] For more on information on how management unit recovery planners calculated population-specific conservation gaps in terms of the VSP parameters, see pp. 58 to 78 of ODFW (2010) and pp. 4-28 through 4-30 of LCFRB (2010a).

Although population-specific gap analyses are subject to a significant level of uncertainty that is difficult to quantify, management unit planners and NMFS consider the results of these analyses useful in conveying the order of magnitude of improvements that need to be addressed through recovery strategies and actions.

Quantification of population-specific gaps in abundance and productivity is one area where Oregon and Washington recovery planners took slightly different approaches in their analyses. In calculating the abundance and productivity improvements needed to achieve each population's target status, Oregon recovery planners built in two numerical "buffers": one to account for expected future threats (i.e., climate change and human population growth in the region), and one to serve as a "safety factor," to compensate for scientific uncertainty and possible measurement errors. In contrast, Washington recovery planners based their calculations of needed abundance and productivity improvements on known baseline conditions and expect to respond to future threats and account for scientific uncertainty through adaptive management.

A result of this difference in approach to future threats and scientific uncertainty is that the numerical estimates of abundance and productivity needed to fill the conservation gaps for Oregon populations are bigger than those for corresponding gaps for the Washington populations. NMFS' view is that this difference in approach is not significant because (1) management unit recovery planners did not do quantitative modeling of the probable effects of recommended recovery actions, and (2) both states will rely on adaptive management as actions are implemented and conditions in the region change.

## 5.3 Limiting Factors and Threats

NMFS defines limiting factors as various biological, physical, or chemical conditions (such as high water temperatures) and the associated ecological processes and interactions that limit a species' viability[5]; NMFS defines threats as human activities or natural events that cause or contribute to limiting factors. For example, the limiting factor of high water temperature could be caused by any number of threats, either alone

each population (based on McElhany et al. 2004) and a target status for each population (based on LCFRB 2010a).

[4] The Oregon management unit plan contains explicit targets for spatial structure and diversity; in the Washington management unit plan, spatial structure and diversity improvements are implicit in the abundance and productivity targets.

[5] In this recovery plan, the term "limiting factors" is used to indicate the full range of factors that are believed to be impairing the viability of salmon and steelhead and not to indicate the single factor that is most limiting. Some NMFS scientists are now using the term "ecological concerns" instead of "limiting factors" to connote this full range of factors affecting viability.

or in combination, such as warm water discharged to a stream, loss of bank vegetation that otherwise would shade the stream, low stream flow, or climate change. Threats can be caused by past or present actions or events. Understanding threats allows recovery planners to identify actions that will change the actual activities or events that cause a limiting factor, thus reducing the limiting factor itself.

The management unit recovery planners identified population-specific limiting factors and threats that are contributing to the threatened status of Lower Columbia River ESUs through review and synthesis of published and unpublished literature, supplemented by EDT modeling (for Washington populations) and professional judgment (for Oregon and White Salmon populations). Each management unit plan presents limiting factors for all populations within its planning area (see, for example, Table 5-1 of ODFW 2010), with impacts falling into six associated threat categories: tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation (or ecological interactions, in the Washington management unit plan). The management unit plans describe limiting factors and threats in relation to the biological needs of the species and across the full spectrum of conditions that affect salmon and steelhead throughout their life cycle. Because data linking limiting factors to specific effects on population risk status are generally lacking, each management unit plan presents the limiting factors as hypotheses to be tested through action implementation and monitoring of results, with adaptive management as needed.

Oregon recovery planners used a multi-step process to identify limiting factors and threats. Using available published and unpublished information and professional judgment, an expert panel developed an initial set of population-level limiting factors and threats by life stage (juvenile or adult) and categorized them as having either a key or secondary impact on population status.[6] The Oregon recovery planning team and the Oregon Lower Columbia River stakeholder team then worked iteratively to review the initial set of limiting factors and threats and modify them based on additional information and deliberation. For additional discussion of the expert panel process and detailed results for each population, see Chapter 5 of ODFW (2010).

Washington recovery planners based their descriptions of limiting factors and threats on review and synthesis of published and unpublished literature for the listed species in the lower Columbia region. They also used Ecosystem Diagnosis and Treatment (EDT) modeling to identify primary and secondary habitat limiting factors by juvenile and adult life stages at the population and stream reach scale. Detailed results of the EDT modeling are presented in Volume II of the LCFRB plan and are reflected in the population-level limiting factors reported in this ESU-level recovery plan (see Section 5.4 and Appendix H).

White Salmon recovery planners identified limiting factors and threats based on a substantial body of research, local field data and observations, and the opinions of regional experts (NMFS 2013).

[6] For discussion of the thresholds used to determine whether a factor was key or secondary, see Section 5.1.4 of ODFW (2010).

## 5.4 NMFS Limiting Factors Crosswalk

Each of the management unit plans use somewhat different terms to describe limiting factors and threats, and in some cases, the plans characterize limiting factors and threats at different levels of specificity. To facilitate the use of a common parlance in discussing limiting factors in all salmon and steelhead recovery plans, the NMFS Northwest Fisheries Science Center developed a standardized set of limiting factors (also known as ecological concerns) that affect salmon and steelhead (Hamm 2012). NMFS refers to this standardized list of limiting factors as a "data dictionary" and intends to use it to track and report on recovery plan limiting factors and actions regionwide. For this recovery plan, NMFS developed a set of limiting factor "crosswalk" tables that correlate each management unit plan's population-specific limiting factor information with the terms used in the data dictionary. Appendixes G and H present the data dictionary and crosswalk tables, respectively.

The crosswalk tables indicate the limiting factors (i.e., the "ecological concerns" in the data dictionary) that affect each population, as well as the life stage affected, the degree of impact (primary or secondary), the location of the impact (in tributaries or in the Columbia River estuary and plume), and, in certain cases, whether there is uncertainty regarding the accuracy of the data. NMFS used the crosswalk tables in Appendix H to derive the summaries of stratum- and ESU-level limiting factors and threats in Chapters 6 through 9 of this ESU recovery plan.

Appendix H explains the methodology that NMFS used to develop the limiting factor crosswalks. Briefly, the limiting factors identified in the Oregon management unit plan tracked quite readily to the subcategories of ecological concerns in the Northwest Fisheries Science Center data dictionary. For Washington populations, it was necessary for NMFS staff and an independent contractor to examine the EDT results, draw information from various parts of the Washington management unit plan, and confer with Lower Columbia Fish Recovery Board staff and the board's consultant to distinguish between primary and secondary limiting factors.

## 5.5 Baseline Threat Impacts

Once management unit recovery planners had identified population-specific limiting factors, they estimated the baseline mortality impacts to each population caused by six categories of threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation (or ecological interactions, in the Washington management unit plan)—that also proved useful as an organizing construct for grouping limiting factors. Only potentially manageable impacts were considered. In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., impacts reflect the mortality of fish exposed to that particular category of threats, whether or not they are exposed to threats in the other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the baseline threat impacts provide a reasonable estimate of the relative magnitude of

different sources of anthropogenic mortality on each population and serve as an adequate basis for designing initial recovery actions. As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

Management unit recovery planners used the population-specific baseline threat impacts when (1) evaluating the effects of possible reductions in each threat category (see Tables 6-6, 7-6, 7-8, 7-10, 8-4, and 9-7), and (2) scaling actions to achieve the target status for each population (see Section 5.7, "Recovery Strategies and Actions").

### 5.5.1 Oregon Approach to Quantifying Baseline Threat Impacts

Oregon recovery planners estimated the baseline impacts of threats as summarized below:

- Hydropower impacts: Estimated dam passage mortality among juveniles and adults based on estimates in the 2008 FCRPS Biological Opinion (NMFS 2008f) or FERC relicensing documents, and in some cases professional judgment. Excluded non-passage impacts such as habitat blockage, habitat inundation, and flow modification in the Columbia River estuary.

- Harvest impacts: Calculated average fishery exploitation rates for a reference period that extends loosely from 1994 to 2004 (ODFW 2010 p. 72-74 and Table 4-8, p. 73).

- Hatchery impacts: Estimated hatchery impacts as mortality resulting from the reduced overall population productivity of natural-origin fish; assumed that mortality corresponds to the proportion of hatchery fish in natural spawning populations (except for Chinook salmon populations, where hatchery impact rates were assumed to be one-half the rates at which hatchery fish were found on natural spawning grounds; see pp. 156 to 158 of ODFW 2010). This approach reflects a concern for both the genetic and ecological effects of hatcheries and excludes the benefits of conservation hatchery programs.

- Predation impacts: Estimated overall predation rates based on information in the literature and then adjusted those rates downward to exclude non-anthropogenic predation.

- Estuary habitat impacts: Derived estimates of baseline mortality from estimates of total juvenile mortality in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). Adjusted the module estimates downward assuming that 70 percent of subyearling migrant mortality and 35 percent of yearling migrant mortality in the estuary is anthropogenic. Further adjusted the estimates downward to subtract estimated mortality that is due to predation on juveniles.

- Tributary habitat impacts: Estimated the baseline mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the baseline

modeled abundance and estimated historical abundance) to tributary habitat impacts.

Throughout the Oregon management unit plan, ocean conditions were considered to be part of the environmental, variable baseline and thus not a discrete threat. However, the Oregon management unit plan notes that anthropogenic impacts in the ocean and other locations may be increasing, and that past assumptions about natural variability may not hold true in the future. Oregon recovery planners increased the size of the abundance and productivity gap by 20 percent in part to account for effects of future climate change, including changes in ocean conditions.

Oregon recovery planners did not quantify baseline and target threat impacts for chum salmon populations because data were inadequate to do so.

For more detailed information on how Oregon recovery planners estimated baseline threat impacts, see Section 6.2.1 of ODFW (2010).

### 5.5.2 Washington Approach to Quantifying Baseline Threat Impacts

Washington recovery planners estimated the baseline impact of threats as summarized below:

- Hydropower impacts: Estimated impacts from dam passage mortality, habitat loss caused by inundation, and loss of access to historical production areas because of the presence of large, impassable tributary and mainstem dams; excluded indirect hydropower impacts. Inferred the production potential of inaccessible habitat from EDT results. Estimated mainstem hydropower impacts based on the *Recovery Plan Module: Mainstem Columbia River Hydropower Projects* (NMFS 2008a).

- Harvest impacts: Used baseline fishery impacts rates from a reference period in the late 1990s; rates included harvest and indirect mortality and generally reflected the maximum estimated impacts.

- Hatchery impacts: Estimated hatchery impacts as mortality resulting from reduced overall population productivity of natural-origin fish; assumed that mortality is a function of the proportion and productivity of hatchery-origin fish that are spawning naturally. Inferred estimates of the relative fitness of hatchery- and natural-origin spawners from Columbia River Hatchery Scientific Review Group (HSRG) analyses. Limited hatchery impacts to not more than 50 percent per population, in accordance with HSRG assessments of the potential for genetic effects. Excluded impacts from interactions between hatchery- and natural-origin fish and the beneficial impacts of conservation hatchery programs.

- Ecological interactions: Estimated aggregate predation rates in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants, based on a combination of data, anecdotal information, and clearly articulated assumptions.

- Estuary habitat impacts: Derived estimates of baseline mortality from estimates of total juvenile mortality in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). Excluded predation mortality and assumed that manageable habitat mortality in the estuary was half of the non-predation-related total mortality.

- Tributary habitat impacts: Used EDT to derive estimates of the relative reduction in fish numbers resulting from changes in stream habitat conditions compared to a historical template.

Washington recovery planners did not quantify the effects of ocean conditions and long-term climate changes because of uncertainty about the magnitude and timing of their effects. However, the effects of normal variability in ocean conditions on annual fish survival were accounted for in the models that were used to evaluate population-level abundance and productivity and to establish abundance and productivity goals and threat reduction targets. The Washington management unit plan intends to address potential future changes in ocean and climate effects through adaptive management, prioritization of habitat restoration and protection actions, and setting recovery goals higher than necessary to achieve delisting (see Section 5.9 of LCFRB 2010a).

For more detailed information on how Washington recovery planners estimated baseline threat impacts, see Sections 3.7.2 through 3.7.4 of LCFRB (2010a).

### 5.5.3 White Salmon Approach to Quantifying Baseline Threat Impacts

The White Salmon management unit plan does not include an analysis of the baseline threat impacts. However, Washington recovery planners developed baseline threat impacts for the White Salmon populations to facilitate establishment of ESU-level recovery scenarios (see LCFRB 2010a). These threat impacts will be used to inform implementation and monitoring for the White Salmon management unit plan.

## 5.6 Threat Reduction Scenarios

Once management unit planners had quantified the baseline impacts of the six categories of threats (tributary habitat, estuary habitat, dams, harvest, hatcheries, and predation), they were able to evaluate the effects of possible reductions in each threat category. In this recovery plan, a given combination of threat reduction targets that would lead to a population achieving its target status is termed a threat reduction scenario. The scenario describes how much of a gain in population abundance and productivity is needed from recovery actions in each threat category to achieve a population's target status.

For each Oregon population, recovery planners developed and evaluated multiple threat reduction scenarios and then selected one. Washington recovery planners, on the other hand, developed a single threat reduction scenario for each population by assigning threat reduction targets to the six threat categories in proportion to the baseline impacts of each category. The different management unit plan approaches to developing threat reduction scenarios and population-specific threat reduction targets

are summarized below. For more detail, see Section 4.5.2 of LCFRB (2010a) and Section 6.2.1 of ODFW (2010).

### 5.6.1 Oregon's Threat Reduction Scenarios

Oregon recovery planners evaluated how a number of different combinations of reductions in the six threat categories would affect each population's persistence probability. Evaluating multiple combinations of threat reductions across the six categories allowed the planning team and stakeholders to examine the tradeoffs among the various threat reduction options.

Oregon recovery planners evaluated the following threat reduction scenarios for each population:

- 20 percent reduction in each threat category's baseline rate
- Maximum harvest and hatchery (assumes essentially zero harvest, with a remaining 5 percent incidental impact rate, eliminating all LCR hatchery programs, and maintaining other threats at baseline levels)
- Maximum feasible reduction (assumes reductions in all threat categories that were considered feasible with current biological, social, political, and economic realities)
- Minimum tributary habitat (explores the minimum tributary habitat impact reduction required if reductions in other threat categories are maximized)
- Maintain into future (evaluates the threat reductions needed in each category to achieve a 20 percent increase in abundance to account for unknown future threats and maintain baseline risk status)
- Low extinction risk (evaluates the threat reductions needed to achieve low extinction risk, i.e., high persistence probability)
- Very low extinction risk (evaluates the threat reductions needed to achieve very low extinction risk, i.e., very high persistence probability)

The first four scenarios evaluated the persistence probability that would result from reducing two or more threat categories a given amount; the last three scenarios evaluated the threat reductions necessary to achieve a specific persistence probability.

Eventually, Oregon recovery planners selected a specific threat reduction scenario for each population based on factors such as feasibility, societal goals (including harvest opportunity, in some cases), and consistency with the WLC TRT's viability criteria. In addition, for the selected threat reduction scenario, Oregon assigned a level of confidence of whether the reductions could be achieved. In some cases the confidence was low. For more information on how Oregon developed its threat reduction scenarios, see Section 6.2.1 of ODFW (2010).

Once Oregon recovery planners had selected a threat reduction scenario, they used a simple, independent, threat impact model to apportion the needed abundance and

productivity improvements (which had been calculated as part of the gap analysis) across the six threat categories, in accordance with the selected scenario.

### 5.6.2 Washington's Threat Reduction Scenarios and Interim Benchmarks

Washington recovery planners developed a single threat reduction scenario for each population, setting a target impact level for each threat category that reflects long-term future conditions when recovery objectives are achieved. To establish these threat reduction targets, planners distributed the needed abundance and productivity improvements across the threat categories in proportion to the baseline impacts of each category. This was a policy decision by the Lower Columbia Fish Recovery Board that will lead to each sector being responsible for reducing its impacts in proportion to its contribution to the total baseline impacts. Thus, sectors with small baseline impacts are responsible for effecting a smaller reduction than sectors with large baseline impacts.

Washington recovery planners calculated proportionate reductions in each threat category directly from the population productivity improvement targets identified in the conservation gap analysis. The resulting impact reduction targets provide guidance on the scale of threat-specific improvement that must be accomplished by threat-specific strategies and measures.

The Washington management unit plan's threat reduction targets do not explicitly consider the timing of recovery action implementation, or the potential lag time in the realization of benefits. Some threats respond quickly to actions aimed at reducing them, while others respond more slowly. For example, reductions in harvest translate into immediate increases in survival and abundance, while the benefits of hatchery and habitat measures typically take much longer to be realized. To address this problem and provide some immediate reductions in extinction risk (until the benefits of all recovery measures can be realized), the Washington management unit plan includes a schedule of interim threat reduction benchmarks that, for some threat categories, define relatively large reductions in impacts in the near term; specific values were determined based on a combination of biological benefits and implementation feasibility. The benchmarks also include a combination of action implementation, impact reduction, and biological improvement standards by which recovery plan implementation can be scheduled and evaluated. The interim benchmarks are presented in Tables 6-3, 6-4, 6-8, 6-11, and 6-14 of LCFRB (2010a).

### 5.6.3 White Salmon Threat Reduction Scenarios

The White Salmon management unit plan does not include an analysis of the relative impact of baseline threat categories or the reductions needed in each threat category to reach recovery targets. However, Washington recovery planners developed threat reduction scenarios for the White Salmon populations to facilitate establishment of ESU-level recovery scenarios (see LCFRB 2010a). With the removal of Condit Dam, these threat reduction scenarios will need to be reevaluated as new information about conditions in the White Salmon subbasin becomes available.

## 5.7 Recovery Strategies and Actions

The threat reduction targets provided a foundation from which management unit recovery planners could identify and scale recovery strategies and actions intended to reduce threats by the targeted amount in each category. The actions in the management unit plans address threats across the entire salmonid life cycle and include a balance of (1) actions intended to provide relatively immediate benefits, and (2) actions whose benefits are expected to be realized over a longer period of time. The management unit plans recommend both new activities and the continuation of existing programs that currently are benefiting Lower Columbia River ESUs (ODFW 2010, LCFRB 2010a). Actions identified in the management unit plans are intended to reduce threats in each category consistent with the conservation gaps and threat reduction targets described in Sections 5.2.2 and 5.6.

The Oregon and Washington management unit plans emphasize that recovery success will require not just local action but combined effort at the state, regional, national, and—in the case of harvest and hydropower—international level (ODFW 2010, LCFRB 2010a). Also, because there is a high degree of uncertainty about the biological response to actions and the level to which actions will need to be implemented to achieve the desired benefits, the plans consider proposed actions to some extent as hypotheses that will need to be tested. None of the management unit plans quantified the incremental benefit of any specific action; instead, actions were selected and scaled based on scientific judgment. (For a discussion of the sufficiency of recovery actions, see Section 5.8) All three management unit plans stress that adaptive management will play a central role in the recovery process, with research, monitoring, and evaluation activities providing crucial information on the effects of individual actions and overall progress toward recovery goals (ODFW 2010, LCFRB 2010a). (For more on research, monitoring, evaluation, and adaptive management, see Chapter 10.) Background information on recovery strategies and actions is presented in Section 5.1 of LCFRB (2010a) and 7.1 of ODFW (2010) and summarized below.

### 5.7.1 Oregon Approach to Developing Recovery Strategies and Actions

To develop recovery strategies and actions for Oregon populations, Oregon recovery planners began with the limiting factors and threats identified for each population by life stage and location. They then developed 14 overarching recovery strategies to provide an ecological context for identifying recovery actions (see Table 7-1 of ODFW 2010). Each strategy was associated with one or more of the six threat categories and was consistent with goals of biological diversity, ecological integrity, and ecological health (ODFW 2010).

Next, recovery planners developed recovery actions. The Oregon Lower Columbia River stakeholder team, which included state and federal agency staff and representatives of agricultural, commercial, conservation, recreational, forestry, and fishing interests, reviewed the recovery actions and provided additional input. The Oregon management unit plan includes actions that address all key or secondary limiting factors. For some habitat actions, Oregon recovery planners identified specific locations for implementation, using reach-scale assessments, other action plans, and professional

judgment; for some locations, they identified a need for completion of reach-scale assessments so that recovery actions could be targeted to where they are most needed.

Recovery actions in the Oregon management unit plan are organized by species and population (see Tables 7-3B, 7-3C, 7-3D, and 7-3E of ODFW 2010), with specific locations noted separately (see Table 9-3 of ODFW 2010). The threat category that each action addresses is indicated. The plan also identifies actions that address threats common to all Lower Columbia River salmon and steelhead populations (see Table 7-3A of ODFW 2010) and actions that apply to a single ESU or run component at multiple locations.

The Oregon management unit plan recommends that priority be given to recovery actions that do the following:

- Benefit populations that must achieve high persistence probability
- Address a key limiting factor or large conservation gap
- Will protect or result in accessible and connected high-quality habitat
- Are in locations with high intrinsic potential[7]
- Protect threatened high-quality or highly productive habitat
- Provide resiliency against climate change

In addition, Oregon recovery planners suggested funding strategies and recommended quick action for populations targeted for high persistence probability, especially in the case of tributary habitat actions (ODFW 2010).

### 5.7.2 Washington Approach to Developing Recovery Strategies and Actions

Washington recovery planners developed an integrated regional strategy for recovery, a series of threat-specific strategies and measures, and corresponding working hypotheses regarding the facts and assumptions that the strategies and measures are based on. Measures provide initial recovery guidance. Some apply generally to most Lower Columbia River ESUs; others apply to a single species. Measures are categorized based on whether they are existing or new activities and whether they provide primarily protection or restoration benefits (LCFRB 2010a).

To develop the regional strategies and measures, Lower Columbia Fish Recovery Board staff conducted meetings and workshops attended by representatives from affected entities and implementing agencies. The strategies and measures are based on a combination of expected biological results and economic, political, social, and cultural considerations, with the expectation that they will be refined during implementation.

Habitat protection and restoration actions targeted to specific stream reaches are identified in a series of subbasin chapters that constitute Volume II of the Washington

[7] Analyses based on the relationship between certain landscape features (e.g., channel gradients or geology) and species' habitat preferences can form the basis of a consistent approach to evaluating habitat potential to support a particular species. These analyses can inform species conservation and habitat restoration activities. Intrinsic potential models use geospatial data to identify stream reaches with high, low, or no potential to host a particular species. The models rate habitat potential at the level of a stream reach but provide a method for estimating habitat quantity and quality across local or regional scales.

management unit plan (LCFRB 2010a). Washington recovery planners prioritized these actions based on subbasin and stream reach fish production values and habitat limiting factors in all current and historical anadromous production areas. This prioritization considered the needs of the multiple populations within each subbasin. Geographically specific management actions for tributary habitat were developed using EDT and a geographical information system (GIS)-based tool known as the Integrated Watershed Assessment (IWA), which is used to assess stream habitat conditions and watershed process impairments at the subwatershed scale (3,000 to 12,000 acres). For further descriptions of the EDT and IWA analyses, see Chapter 7 and Appendix E of LCFRB (2010a).

### 5.7.3 White Salmon Approach to Developing Recovery Strategies and Actions

Recovery strategies and actions in the White Salmon management unit plan fall into two categories: (1) those aimed at reintroducing naturally produced salmon and steelhead into historical habitat after the removal of Condit Dam and (2) those aimed at improving and increasing freshwater habitat for salmon and steelhead production in key reaches (NMFS 2013). Actions for reintroduction were developed by the White Salmon Working Group, which consisted of federal, state, and tribal fisheries managers and representatives of PacifiCorp (the operator of Condit Dam). For each ESU, the group developed and evaluated a number of reintroduction options and proposed one for implementation. Options are described in more detail in Section 6.1 and Appendix 1 of the White Salmon management unit plan (NMFS 2013).

As part of the White Salmon recovery planning process, NMFS worked with the White Salmon Working Group to review and analyze available information and define freshwater habitat strategies, actions, and priority reaches (NMFS 2013). The habitat strategies and actions include gathering additional information to use in prioritizing actions, protecting existing ecological processes and functioning habitats, restoring vegetation along stream reaches that exceed state standards for water temperature, restoring habitat in the reservoir footprint now that Condit Dam has been removed,[8] and improving habitat in upriver reaches in preparation for the time when reintroduced populations exceed the carrying capacity of the existing habitat.

The White Salmon management unit plan also briefly discusses hatchery, harvest, and hydropower-related strategies and actions (NMFS 2013).

## 5.8 Analysis of Actions

A question relevant to recovery planning is the level of effort that will be required to close the gap between baseline and target population status, and whether the actions identified in the recovery plan are sufficient to attain target status for each population. Because any analysis of such questions involves significant uncertainty, it is essential for any recovery plan to link hypotheses regarding level of effort and sufficiency of actions to rigorous research, monitoring, and adaptive management programs.

[8] Condit Dam was breached in October 2011 and completely removed in September 2012.

Management unit recovery planners addressed the question of the level of effort needed to close conservation gaps by identifying threat reduction targets in each major threat category. They addressed the question regarding sufficiency of actions through varying levels of analysis, depending on threat category, and by taking what the Washington management unit plan termed a "directional approach." The directional approach is based on the hypotheses that (1) the set of actions in this plan is sufficient to establish a trajectory toward recovery, (2) mechanistic analyses of the effects of actions are too uncertain to provide adequate confidence that any initial set of actions will be sufficient, and (3) modifications and refinements will be made as necessary within an adaptive management framework.

As described in the sections above, Oregon and Washington management unit planners did the following:

1. Quantified the abundance and productivity improvements—and in some cases the spatial structure and diversity improvements—needed for each population to move from its baseline persistence probability to its target persistence probability.

2. Quantified the baseline impact on population abundance and productivity for each of six major threat categories.

3. Quantified the amount by which each major threat impact would need to be reduced to close the gap between baseline and target status for each population.

4. Identified strategies and actions in each threat category that are intended to reduce the impact of each threat and improve abundance and productivity by the amount consistent with the target for each population.

Although the management unit planners hypothesized that actions would be sufficient to achieve the targeted threat reductions, the level of analysis carried out to confirm this varied by plan and by threat category. The different approaches in the Washington and Oregon management unit plans make it difficult to generalize; however, in general, the plans provide relatively detailed quantitative documentation for the expected benefits of harvest and hydropower actions. The potential benefits of hatchery, tributary habitat, and estuary habitat actions are assessed systematically but rely more heavily on extrapolations and general assumptions. In some cases, analysis of the sufficiency of actions in the management unit plans is based on professional judgment.

In addition, as part of developing recovery action cost estimates for habitat actions, Washington and Oregon management unit planners developed rough estimates of the number of stream miles that would need to be restored to achieve the habitat improvements targeted in the plans. (In Washington, estimates were for the number of stream miles that would need to be restored in each subbasin, while in Oregon the estimates were species-specific at the population scale; in both cases these estimates were rough and based on multiple assumptions.)

The management unit plans also incorporated monitoring and evaluation programs and an adaptive management framework for implementation to allow us to evaluate whether we are on course and to adjust as needed. This basic approach is useful in

understanding the scale of actions that need to be implemented and in laying the groundwork for understanding and evaluating whether the actions have been effective.

The Washington management unit plan incorporates explicit interim benchmarks, defined as "reference points for planning and evaluating recovery progress over the duration of plan implementation," for action implementation, action effectiveness, and status improvements (see LCFRB 2010a, Section 6.1). The interim benchmarks provided in the Washington management unit plan reflect the incremental implementation strategies described in the plan and explicitly recognize the range in expected response times associated with different actions (e.g., adjustments to harvest rates versus restoring riparian habitats). The interim benchmarks are at 12-year intervals, corresponding to the adaptive management schedule called for in the plan (see LCFRB 2010a, Chapter 10).

The Oregon management unit plan (ODFW 2010) recognizes the importance of periodic assessments of plan performance, although it does not explicitly establish benchmarks equivalent to those in the Washington management unit plan. The adaptive management section of the Oregon management unit plan identifies the need for specific reviews of population status and plan performance at 5-year intervals and recognizes that such reviews would serve as the basis for considering major revisions to the plan on a 12-year cycle (see ODFW 2010, Chapter 9). Although the Oregon management unit plan does not include specific benchmarks, it does provide some general guidance on the expected timing of particular actions (including high-priority research, monitoring, and evaluation efforts) (see ODFW 2010, Section 9.3). This guidance includes specific time frames for full implementation of individual actions (see Table 9-3) and some general guidance on assessing implementation progress for tributary habitat actions ("Note that if the quantity of restoration action indicated in Table 9-2 is divided by the implementation schedule for that action in Section 9.1.3, an annual rate of restoration can be calculated. This can be compared to reported restoration projects and progress toward these habitat recovery action goals can be tracked").

## 5.9 Research, Monitoring, and Evaluation

Strategic research, monitoring, and evaluation (RME) programs that are designed to inform key questions and critical uncertainties and to feed information into an adaptive management framework are key components of salmon and steelhead recovery plans. The management unit plans contain or will contain specific RME plans for their areas. (See Chapter 8 of ODFW 2010 and Chapter 9 of LCFRB 2010a.) These RME plans are based on regional guidance for adaptive management and RME and will guide recovery planning RME efforts and funding in their respective areas, within a context of ongoing regional guidance and coordination. Chapter 10 of this plan describes RME in more detail.

As Chapter 10 also describes, a number of regional entities, including NMFS, are involved in research, monitoring, and evaluation for salmon and steelhead recovery. One component of the RME system for recovery planning is the NMFS 5-year reviews, which are described briefly below because of their relevance to the baseline population status completed by the management unit planners. The NMFS 5-year reviews are discussed in more detail in Chapter 10.

## 5.10 NMFS 2011 5-Year Reviews

Because the management unit plans evaluated baseline status several years ago, when the plans were in development, it is reasonable to ask whether the status of any population has changed since those assessments. Under ESA section 4(c)(2)(B), NMFS is required to conduct a review of listed species at least once every 5 years. Based on such reviews, NMFS determines whether any species should be removed from the list (i.e., delisted) or reclassified from endangered to threatened or from threatened to endangered. During these reviews, NMFS considers the best scientific and commercial data available. In 2011, NMFS published a 5-year review covering the period 2005-2010 that included review of the four species addressed by this recovery plan (76 *Federal Register* 50448). In the 2011 5-year review, NMFS generally relied on information through 2008 or 2009. Evaluation methods and information on species' status will continue to evolve and be updated over time. NMFS' next 5-year review will provide updated summaries of species' status based on best available information.

For the 2011 review, the NMFS Northwest Fisheries Science Center collected and analyzed new information about ESU and DPS viability, using the viable salmonid population concept developed by McElhany et al. (2000) (Ford 2011). NMFS Northwest Region salmon management biologists also reviewed the status of the ESA section 4(a)(1) listing factors (NMFS 2011b).

The updated 5-year review indicates that, although a number of populations in each ESU or DPS have high or medium persistence probability, not a single stratum in any of the ESUs or DPS is currently viable. Multiple populations in each stratum of each ESU or DPS will need improved status to meet the recovery criteria. Although little improvement in ESU or DPS viability has been observed over the last 5 years, there is also no new information to indicate that the extinction risk has increased. In addition, NMFS' analysis of ESA section 4(a)(1) factors indicates that the collective risk to the persistence of the Lower Columbia River Chinook, coho, and steelhead and Columbia River chum has not changed significantly since NMFS' final listing determination in 2006. The 2011 review emphasizes the importance of continuing to implement recovery actions that address the factors limiting population viability, as well as the importance of monitoring the effects of the actions over time.

# 6. Lower Columbia River Coho Salmon

## 6.1 Coho Salmon Biological Background

### 6.1.1 Coho Salmon Life History and Habitat

Lower Columbia River coho salmon (*Oncorhynchus kisutch*) are typically categorized into early- and late-returning stocks. Early-returning (Type S) adult coho salmon enter the Columbia River in mid-August and begin entering tributaries in early September, with peak spawning from mid-October to early November. Late-returning (Type N) coho salmon pass through the lower Columbia from late September through December and enter tributaries from October through January. Most spawning occurs from November to January, but some occurs as late as March (see Figure 6-1) (LCFRB 2010a). Migration and spawning timing of specific local populations may be mediated by factors such as latitude, migration distance, flows, water temperature, maturity, or migration obstacles (ODFW 2010). For example, coho salmon spawning in warmer tributaries spawn later than those spawning in colder tributaries (LCFRB 2010a).

Historically, coho salmon spawned in almost every accessible stream system in the lower Columbia River (LCFRB 2010a). Coho salmon generally occupy intermediate positions in tributaries, typically further upstream than chum or fall-run Chinook, but often downstream of steelhead or spring-run Chinook (ODFW 2010). Early-run fish usually spawn farther upstream within a basin than late-run fish. Coho salmon typically spawn in small to medium, low- to-moderate elevation streams from valley bottoms to stream headwaters. Coho salmon particularly favor small, rain-driven, lower elevation streams characterized by relatively low flows during late summer and early fall, and increased river flows and decreased water temperatures in winter (LCFRB 2010a). On their return, adult fish often mill near the river mouths or in lower river pools until the first fall freshets occur (LCFRB 2010a).

Coho salmon construct redds in gravel and small cobble substrate in pool tailouts, riffles, and glides, with sufficient flow depth for spawning activity (NMFS 2013). Eggs incubate over late fall and winter for about 45 to 140 days, depending on water temperature, with longer incubation in colder water. Fry may thus emerge from early spring to early summer (ODFW 2010). Hatching success depends on clean gravel that is not choked with sediment or subject to extensive scouring by floods (LCFRB 2010a).

Juveniles typically rear in freshwater for more than a year. After emergence, coho salmon fry move to shallow, low-velocity rearing areas, primarily along the stream edges and inside channels. Juvenile coho salmon favor pool habitat and often congregate in quiet backwaters, side channels, and small creeks with riparian cover and woody debris. Side-channel rearing areas are particularly critical for overwinter survival, which is a key regulator of freshwater productivity (LCFRB 2010a).

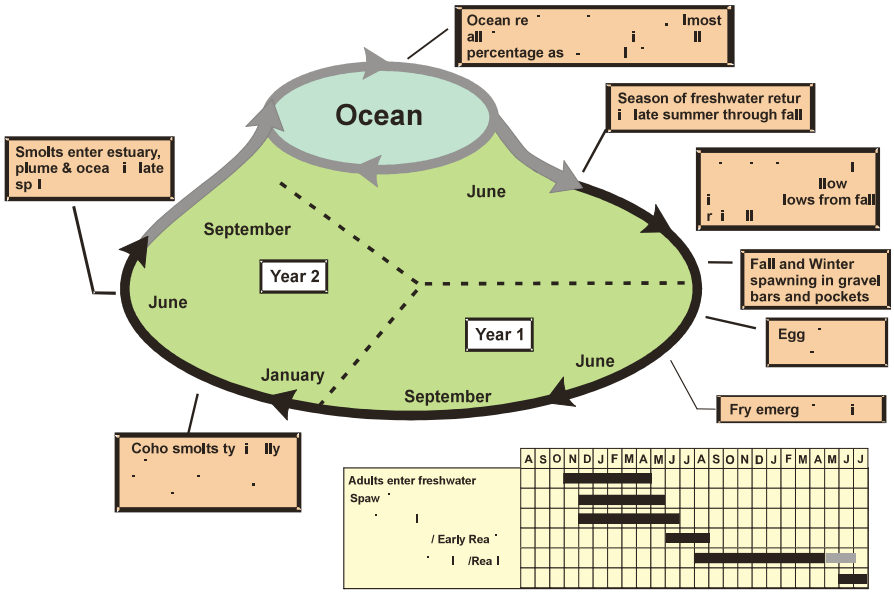


**Figure 6-1.** *Life Cycle of Lower Columbia River Coho Salmon*
(Source: LCFRB 2010a)

The key freshwater habitat needs of Lower Columbia River coho salmon at different life stages are shown in Table 6-1.

**Table 6-1**
*Key Habitat for Coho Salmon, by Life Stage*

| Life Stage | Key Habitat Descriptions |
|---|---|
| Spawning | Riffles, tailouts, and the swifter areas in glides containing a mixture of gravel and cobble sizes with flow of sufficient depth for spawning activity |
| Incubation | As for spawning, but with sufficient flow for egg and alevin development and protection from high flow scour |
| Fry Colonization | Shallow, slow-velocity areas within the stream channel, including backwater areas, often associated with stream margins and back eddies and usually in relatively low-gradient reaches |
| Active Rearing | Relatively slow-water habitat types, often near velocity shears, often associated with relatively low-gradient stream channel reaches, including primary pools, backwaters, tailouts, glides, and beaver ponds |
| Inactive Rearing | Non-turbulent habitat types, particularly deeper water types within the main channel, but also including slower portions of large cobble riffles |
| Migrant | All habitat types having sufficient flow for free movement of juvenile migrants and adequate structure for protection from predators |
| Pre-Spawning Migrant | All habitat types having sufficient flow for free movement of sexually mature adult migrants |
| Pre-Spawning Holding | Relatively slow, deep-water habitat types typically associated with (or immediately adjacent to) the main channel |

Source: Adapted from Northwest Power and Conservation Council (2004b) and McElhany (2010).

Most juvenile coho salmon migrate seaward as smolts in April to June, typically during their second year. Salmon that have stream-type life histories, such as coho, typically do

not linger for extended periods in the Columbia River estuary, but the estuary is a critical habitat used for feeding during the physiological adjustment to salt water. Juvenile coho salmon are present in the Columbia River estuary from March to August (LCFRB 2010a).

Columbia River coho salmon typically range throughout the nearshore ocean over the continental shelf off of the Oregon and Washington coasts. Early-returning (Type S) coho salmon are typically found in ocean waters south of the Columbia River mouth. Late-returning (Type N) coho salmon are typically found in ocean waters north of the Columbia River mouth (LCFRB 2010a). Coho salmon grow relatively quickly in the ocean, reaching up to 6 kilograms after about 16 months of ocean rearing (ODFW 2010). Most coho salmon sexually mature at age three, except for a small percentage of males (called "jacks") who return to natal waters at age two, after only 5 to 7 months in the ocean (LCFRB 2010a). All coho salmon die after spawning. Weather-related upwelling patterns in the ocean and the short 3-year life cycle of this species cause highly variable population cycles (LCFRB 2010a).

### 6.1.2 Historical Distribution and Population Structure of LCR Coho Salmon

The Lower Columbia River coho salmon ESU historically consisted of a total of 24 independent populations (see Table 6-2). Because NMFS had not yet listed the ESU in 2003 when the WLC TRT designated core and genetic legacy populations for other ESUs, there are no such designations for Lower Columbia River coho salmon. However, the Clackamas and Sandy subbasins contain the only populations in the ESU that have clear records of continuous natural spawning (McElhany et al. 2007). Figure 6-2 shows the historical geographical distribution of Lower Columbia River coho salmon strata and populations.[1]

[1] Willamette Falls, on the Willamette River at Oregon City, Oregon, marked the historical upstream extent of coho salmon in the Willamette River. Coho salmon now spawn above Willamette Falls because a fish ladder constructed there in the late-nineteenth century allows them to pass the falls in low flow conditions that would have prevented their passage historically and because hatchery coho salmon were introduced above the falls. In its 2005 listing decision, NMFS noted that coho salmon spawning above Willamette Falls were not considered part of the Lower Columbia River coho ESU (70 *Federal Register* 37160).

**Table 6-2**
*Historical LCR Coho Salmon Populations*

| Stratum | Historical Populations | Early or Late Stock* |
|---|---|---|
| Coast | Youngs Bay (OR) | Late |
| | Grays/Chinook (WA) | Late |
| | Big Creek (OR) | Late |
| | Elochoman/Skamokawa (WA) | Late |
| | Clatskanie (OR) | Late |
| | Mill/Abernathy/Germany (WA) | Late |
| | Scappoose (OR) | Late |
| Cascade | Lower Cowlitz (WA) | Late |
| | Upper Cowlitz (WA) | Early, late |
| | Cispus (WA) | Early, late |
| | Tilton (WA) | Early, late |
| | SF Toutle (WA) | Early, late |
| | NF Toutle NF (WA) | Early, late |
| | Coweeman (WA) | Late |
| | Kalama (WA) | Late |
| | NF Lewis (WA) | Early, late |
| | EF Lewis (WA) | Early, late |
| | Salmon Creek (WA) | Late |
| | Clackamas (OR) | Early, late |
| | Sandy (OR) | Early, late |
| | Washougal (WA) | Late |
| Gorge | Lower Gorge (WA & OR) | Late |
| | Upper Gorge/White Salmon (WA) | Late |
| | Upper Gorge/Hood (OR) | Early |

* This represents the WLC TRT's understanding of the historical run timing for Lower Columbia River coho salmon (i.e., 10 early stocks and 23 late stocks).

Source: Myers et al. (2006).

Up through 2008, 25 artificial propagation programs produced coho salmon considered to be part of this ESU. In 2009, the Elochoman Type-S and Type-N programs were discontinued. In 2011, NMFS recommended that these two programs be removed from the ESU (76 *Federal Register* 50448, Jones 2011). Table 6-3 shows the 23 coho salmon hatchery programs that currently are included in the ESU. For a list of coho salmon hatchery programs not included in the ESU, see Jones (2011).

**Table 6-3**
*Artificial Propagation Programs Included in the LCR Coho Salmon ESU**

| Washington Programs | Oregon Programs |
|---|---|
| Grays River | Big Creek Hatchery |
| Sea Resources Hatchery | Astoria High School (STEP) |
| Peterson Project | Warrenton High School (STEP) |
| Cathlamet High School FFA Type N | Eagle Creek National Fish Hatchery |
| Cowlitz Type N - Upper Cowlitz | Sandy Hatchery |
| Cowlitz Type N -Lower Cowlitz | Bonneville/Cascade/Oxbow complex |
| Cowlitz Game and Anglers Program | |
| Friends of the Cowlitz Program | |
| North Fork Toutle River Hatchery | |
| Kalama River Type S | |
| Kalama River Type N | |
| Lewis River Type S | |
| Lewis River Type N | |
| Washougal Type N | |
| Fish First Wild Coho Salmon | |
| Fish First Type N | |
| Syverson Project Type N | |

* Hatchery programs that are listed as Type S or Type N in this table but that do not correspond to the run timings in Table 6-2 likely will be reevaluated for inclusion/exclusion in the ESU at some point in the future.
Source: 70 *Federal Register* 37178, 76 *Federal Register* 50448, and Jones (2011).

## 6.2 Baseline Population Status of LCR Coho Salmon

Out of the 24 populations that make up this ESU, 21 are considered to have a very low probability of persisting for the next 100 years (see Figure 6-2), and none is considered viable (LCFRB 2010a, ODFW 2010, Ford 2011).[2] All three strata in the ESU fall significantly short of the WLC TRT criteria for viability.

The very low persistence probability for most Lower Columbia River coho salmon populations is related to low abundance and productivity, loss of spatial structure, and reduced diversity. Although poor data quality prevents precise quantification, most populations are believed to have very low abundance of natural-origin spawners (50 fish or fewer, compared to historical abundances of thousands or tens of thousands); data

[2] As described in Section 2.6, the WLC TRT recommended methods for evaluating the status of Lower Columbia River salmon and steelhead populations. The TRT approach is based on evaluating the population parameters of abundance, productivity, spatial structure, and diversity and then integrating those assessments into an overall assessment of population persistence probability. As also described in Section 5.1, management unit recovery planners evaluated their respective populations' baseline status in a manner generally consistent with the WLC TRT's approach, with the baseline period being circa 1999 (for Washington populations) or 2006-2008 (for Oregon populations). Unless otherwise noted, NMFS and the management unit planners believe that those assessments accurately reflect the status of the population at that time; the assessments are the basis for the summaries presented here and are consistent with the conclusions of the Northwest Fisheries Science Center in its *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act* (Ford 2011). New information on population status will continue to accumulate over time and will be taken into account as needed to reflect the best available science regarding a population's status.

quality has been poor because of inadequate spawning surveys and, until recently, the presence of unmarked hatchery-origin spawners.[3] The spatial structure of some populations is constrained by migration barriers (such as tributary dams) and development in lowland areas. Low abundance, past stock transfers, other legacy hatchery effects, and ongoing hatchery straying may have reduced genetic diversity within and among coho salmon populations (LCFRB 2010a, ODFW 2010). It is likely that hatchery effects have also decreased population productivity.

Only in the Clackamas and Sandy subbasins is there a clear record of continuous natural spawning from the 1990s to the present. Spawner abundance for both these populations is, however, still well below long-term minimum abundance thresholds, although there was a generally positive trend from the 1990s through 2005 (Ford 2011). More recent spawning surveys indicate short-term increases in natural production in the Clatskanie, Scappoose, and Mill/Abernathy/Germany populations (ODFW 2010, Ford 2011). Although McElhany et al. (2007) and ODFW (2010) reached the same conclusions about the persistence probability of most Oregon coho salmon populations, conclusions for three Oregon populations (the Scappoose, Clackamas, and Sandy) did change as a result of considering additional years of data and adjusting the risk models used by Oregon in the assessments (ODFW 2010).[4]

The generally poor baseline population status of coho salmon reflects long-term trends: natural-origin coho salmon in the Columbia Basin have been in decline for the last 50 years (ODFW 2010).[5] For additional discussion of Lower Columbia River coho salmon population status, see the management unit plans (LCFRB 2010a, pp. 6-44 through 6-47; ODFW 2010, Chapter 4; and NMFS 2013, p. 4-2) and Ford (2011).

[3] Since 1997, all Lower Columbia River hatchery coho salmon have been marked, and both Oregon and Washington have begun efforts to identify and address data gaps for coho salmon. Unmarked, out-of-ESU coho salmon released in the Klickitat subbasin may stray into the Hood subbasin; these fish are expected to be marked in the near future.

[4] It is particularly notable that the Sandy coho salmon population was assigned a higher risk rating for abundance and productivity in the ODFW (2010) assessment than in the McElhany et al. (2007) assessment; however, although the abundance and productivity risk category changed, the relative gap between current abundance and target abundance did not change appreciatively.

[5] Coho populations upstream of Hood River have been extirpated (ODFW 2010).

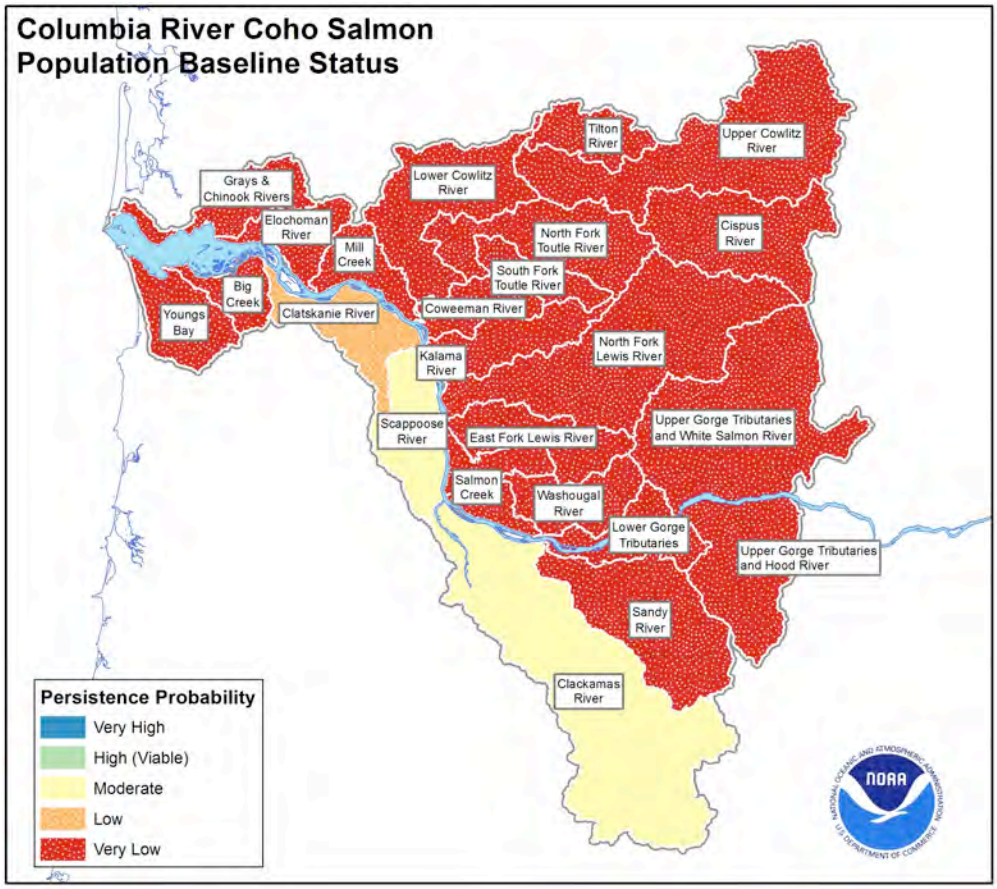


**Figure 6-2.** *Baseline Status of Historical LCR Coho Salmon Populations*

## 6.3 Target Status and Conservation Gaps for Coho Salmon Populations

Table 6-4 shows the baseline and target status for each Lower Columbia River coho salmon population, along with historical and target abundance. Local recovery planners coordinated with NMFS in making decisions about the target status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities. (Note: the target statuses in Table 6-4 are the same as the persistence probabilities in the recovery scenario presented in Table 3-1 in Section 3.1.3.) As described in Section 5.1.4, although Oregon and Washington recovery planners used somewhat different methodologies to estimate baseline status and target abundance and productivity, NMFS and the management unit planners agree that the methodologies led to similar conclusions regarding the very low baseline status for most Lower Columbia River coho salmon populations.

Very large improvements are needed in the persistence probability of most coho salmon populations if the ESU is to achieve recovery. For example, 16 of the 24 historical populations are targeted for high or very high persistence probability. Of these, 14 have a low or very low baseline persistence probability. Some level of recovery effort will be needed for every population—even stabilizing populations that are expected to remain

at their baseline status—to arrest or reverse long-tem declining trends. For most populations, meeting recovery objectives will require improvement in all VSP parameters: abundance, productivity, diversity, and spatial structure.

In the Coast stratum, four of seven populations are targeted for high or very high persistence probability. Two populations—Youngs Bay and Big Creek—are not targeted for improvements in their baseline persistence probability of very low. This decision represents a strategic choice to provide harvest opportunity through terminal fisheries targeting hatchery fish in these subbasins; consequently, the proportion of hatchery-origin spawners (pHOS) in these two populations is expected to remain high.

Of fourteen populations in the Cascade stratum, nine are targeted for high or very high persistence probability. The Kalama and Washougal populations are designated as contributing, in part so that fishery enhancement hatchery programs in those subbasins can continue to support harvest. The North Fork Lewis population is designated as contributing in part because of uncertainties regarding the success of reestablishing natural production above tributary dams. Two populations—Salmon Creek and the Tilton—are not targeted for improvements in their baseline persistence probability of very low. The Salmon Creek subbasin is highly urbanized. In the Tilton subbasin, habitat is of lower quality than in the Upper Cowlitz and Cispus subbasins.

All three of the Gorge stratum populations are targeted to move from very low to high persistence probability. However, the Oregon management unit plan notes that the feasibility of meeting abundance and productivity targets for the Upper Gorge/Hood River population (see Table 6-4) is very low. Challenges include the small amount of historical and current habitat (and thus the limited options for restoration); anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of historical spawning habitat by Bonneville Reservoir and roads that restrict access to habitat); high uncertainty in the data and analyses for small populations[6]; and the possibly inaccurate designation of population structure for this stratum. The Oregon management unit plan states that most of these issues are related to the population structure designation and suggests re-evaluating the Gorge stratum population structure for all species (ODFW 2010). As discussed in Section 3.2.1, NMFS agrees that such an evaluation is needed.

If the scenario in Table 6-4 were achieved, it would exceed the WLC TRT's viability criteria, particularly in the Cascade stratum.[7] Exceeding the criteria in the Cascade stratum was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge stratum, in particular the questions raised by Oregon recovery planners about the

[6] In the method used by the WLC TRT and management unit planners to establish abundance goals, target abundance is based to some extent on the gap between current and historical abundance. If the historical abundance of the Upper Gorge/Hood coho population has been significantly overestimated, then the abundance needed to achieve its target status may also be overestimated (ODFW 2010).

[7] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that, using the WLC TRT's scoring system, the average score for all populations in the stratum be 2.25 or higher. In the Cascade stratum, nine populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average score for all populations in the stratum would be 2.39.

feasibility of meeting the target status for the Upper Gorge/Hood population. (Delisting criteria for the Lower Columbia River coho ESU are described in Sections 3.2 and 6.7)

Figure 6-3 displays the population-level conservation gaps for Lower Columbia River coho salmon graphically. The conservation gap reflects the magnitude of improvement needed to move a population from its baseline status to the target status. For additional discussion of targets and conservation gaps for Lower Columbia River coho salmon populations, see the management unit plans (LCFRB 2010a, pp. 6-44 to 6-48; ODFW 2010, pp. 148, 169 to 177; and NMFS 2013, p. 3-12).

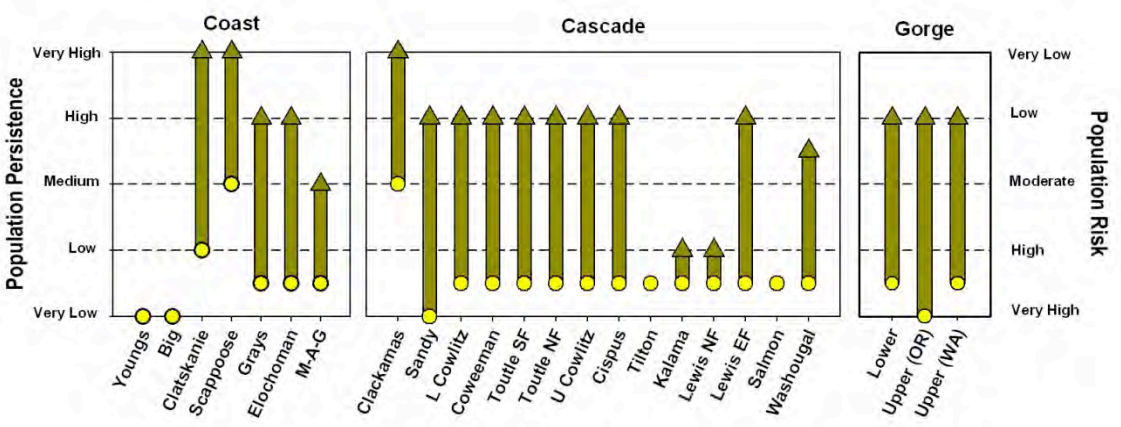


**Figure 6-3.** *Conservation Gaps for LCR Coho Salmon Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

**Table 6-4**

*Baseline and Target Persistence Probability and Abundance of LCR Coho Salmon Populations*

| | | | Baseline Persistence Probability[8] | | | | | Abundance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stratum** | **Population** | **Contribution** | **A&P** | **S** | **D** | **Net** | **Target Persistence Probability** | **Historical** | **Baseline[9]** | **Target** |
| Coast | Youngs Bay (OR) | Stabilizing | VL | VH | VL | VL | VL | 18,588 | 4 | 7 |
| | Grays/Chinook (WA) | Primary | VL | H | VL | VL | H | 3,800 | < 50 | 2,400 |
| | Big Creek (OR) | Stabilizing | VL | H | L | VL | VL | 10,830 | 8 | 12 |
| | Elochoman/Skamokawa (WA) | Primary | VL | H | VL | VL | H | 6,500 | < 50 | 2,400 |
| | Clatskanie (OR) | Primary | L | VH | M | L | VH | 16,781 | 1,363 | 3,201 |
| | Mill/Abernathy/Germany (WA) | Contributing | VL | H | L | VL | M | 2,800 | < 50 | 1,800 |
| | Scappoose (OR) | Primary | M | H | M | M | VH | 22,164 | 1,942 | 3,208 |
| Cascade | Lower Cowlitz (WA) | Primary | VL | M | M | VL | H | 18,000 | 500 | 3,700 |
| | Upper Cowlitz (WA) | Primary | VL | M | L | VL | H | 18,000 | < 50 | 2,000 |
| | Cispus (WA) | Primary | VL | M | L | VL | H | 8,000 | < 50 | 2,000 |
| | Tilton (WA) | Stabilizing | VL | M | L | VL | VL | 5,600 | < 50 | -- |
| | SF Toutle (WA) | Primary | VL | H | M | VL | H | 27,000 | < 50 | 1,900 |
| | NF Toutle (WA) | Primary | VL | M | L | VL | H | | < 50 | 1,900 |
| | Coweeman (WA) | Primary | VL | H | M | VL | H | 5,000 | < 50 | 1,200 |
| | Kalama (WA) | Contributing | VL | H | L | VL | L | 800 | < 50 | 500 |
| | NF Lewis (WA) | Contributing | VL | L | L | VL | L | 40,000 | 200 | 500 |
| | EF Lewis (WA) | Primary | VL | H | M | VL | H | 3,000 | < 50 | 2,000 |
| | Salmon Creek (WA) | Stabilizing | VL | M | VL | VL | VL | --[10] | < 50 | -- |

[8] A&P = Abundance and productivity, S = spatial structure, and D = genetic and life history diversity. Net = overall persistence probability of the population. VL = very low, L = low, M = moderate, H = high, VH = very high.

[9] Baseline abundance was estimated as described in Section 5.1 and does not equal observed natural-origin spawner counts. The baseline is a modeled abundance that represents 100-year forward projections under conditions representative of a recent baseline period using a population viability analysis that is functionally equivalent to the risk analyses in McElhany et al. (2007). Projections generally assume conditions similar to those from 1974 to 2004. Oregon numbers reflect fishery reductions between the 1990s and about 2004, while Washington numbers reflect fishery impacts prevalent circa 1999.

[10] "–" indicates that no data are available from which to make a quantitative assessment.

**Table 6-4**

*Baseline and Target Persistence Probability and Abundance of LCR Coho Salmon Populations*

| | | | Baseline Persistence Probability[8] | | | | | Abundance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stratum** | **Population** | **Contribution** | **A&P** | **S** | **D** | **Net** | **Target Persistence Probability** | **Historical** | **Baseline[9]** | **Target** |
| | Clackamas (OR) | Primary | M | VH | H | M | VH | 52,565 | 6,548 | 11,232 |
| | Sandy (OR) | Primary | VL | H | M | VL | H | 19,647 | 1,622 | 5,685 |
| | Washougal (WA) | Contributing | VL | H | L | VL | M+ | 3,000 | < 50 | 1,500 |
| Gorge | Lower Gorge (WA & OR) | Primary | VL | M | VL | VL | H | -- | < 50 | 1,900 |
| | Upper Gorge/White Salmon (WA) | Primary | VL | M | VL | VL | H | -- | < 50 | 1,900 |
| | Upper Gorge/Hood (OR) | Primary | VL | VH | L | VL | H* | 8,846 | 41 | 5,162 |

*Oregon's analysis indicates a low probability of meeting the delisting objective of high persistence probability for this population.

Source: LCFRB (2010a) and ODFW (2010).

## 6.4 Limiting Factors and Threats for LCR Coho Salmon

Lower Columbia River coho salmon have been—and continue to be—affected by habitat degradation, hydropower impacts, harvest, and hatchery production. The combined effects of these factors have reduced the persistence probability of all Lower Columbia River coho salmon populations.

Table 6-5 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River coho salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4). In addition, in Table 6-5 NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[11] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the White Salmon plan and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of the Lower Columbia Fish Recovery Board's staff and consultants). For populations that historically spawned in the White Salmon subbasin, NMFS staff inferred primary and secondary designations based on discussion in the Washington and White Salmon management unit plans (LCFRB 2010a, NMFS 2013). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting

[11] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

each Lower Columbia River coho salmon population, including magnitude, spatial scale, and relative impact (see LCFRB 2010a, Chapter 3 and various sections of Volume II; ODFW 2010, pp. 102-115; and NMFS 2013, Chapter 5). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 6.5 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

**Table 6-5**

*Baseline Limiting Factors and Threats Affecting LCR Coho Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast | Cascade | Gorge |
|---|---|---|---|---|---|
| **Tributary Habitat Limiting Factors** | | | | | |
| Habitat Quantity | Small dam (irrigation) | All | | | Secondary for Upper Gorge/Hood adults |
| Riparian Condition | Past and/or current land use practices | All | | Primary for juveniles in all populations | |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | | Primary for juveniles in all populations | |
| Peripheral and Transitional Habitats: Side Channel and Wetland Conditions | Past and/or current land use practices/ transportation corridor | All | | Primary for juveniles in all populations | |
| Peripheral and Transitional Habitats: Floodplain Conditions | Past and/or current land use practices/ transportation corridor | All | | Primary for juveniles in all populations | |

**Table 6-5**

*Baseline Limiting Factors and Threats Affecting LCR Coho Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast | Cascade | Gorge |
|---|---|---|---|---|---|
| Sediment Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for WA juveniles; secondary for OR juveniles[12] | Secondary for Clackamas, Sandy, Kalama, and Washougal juveniles; primary for juveniles in all other populations | Secondary for juveniles in all populations |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dams | A,P,D | Secondary for juveniles in all populations | | Secondary for Upper Gorge/White Salmon juveniles[13] and Upper Gorge/Hood juveniles |
| Water Quantity (Flow) | Dams, land use, irrigation, municipal, and hatchery withdrawals | All | Primary for Youngs Bay and Big Creek juveniles; secondary for juveniles in all other populations | Primary for Tilton, Kalama, and Washougal juveniles; secondary for juveniles in all other populations | Primary for Upper Gorge/Hood juveniles (irrigation withdrawals); secondary for juveniles in all other populations |
| **Estuary Habitat Limiting Factors[14]** | | | | | |
| Toxic Contaminants | Agricultural chemicals, urban and industrial practices | A,P,D | Secondary for juveniles in all populations | | |
| Food[15] | Dam reservoirs | All | Secondary for juveniles in all populations | | |

[12] This distinction is likely an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in sediment conditions in tributary streams or their effects on coho populations.

[13] For the Upper Gorge/White Salmon population, water temperature in the mainstem White Salmon River is at or near optimum levels for salmonids. Maximum temperature within the expected range of anadromous fish within the White Salmon subbasin meets Washington state water quality standards, with the exception of Rattlesnake Creek. Rattlesnake Creek is a significant habitat area where water temperature approaches lethal levels in some locations during some years (NMFS 2013).

[14] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 6.4.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River coho salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[15] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is

**Table 6-5**

*Baseline Limiting Factors and Threats Affecting LCR Coho Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast | Cascade | Gorge |
|---|---|---|---|---|---|
| (Shift from macrodetrital- to microdetrital-based food web ) | | | | | |
| Peripheral and Transitional Habitats: Estuary Condition | Past and/or current land use practices/transportation corridor, mainstem dams | All | Secondary for juveniles in all populations | | |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | | |
| Sediment Conditions | Past and/or current land use practices/transportation corridor, dams | All | Primary for juveniles in all populations | | |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow; dam reservoirs | A,P,D | Secondary for juveniles in all populations | | |
| Water Quantity (Flow) | Columbia River mainstem dams | All | Primary for juveniles in all populations | | |
| **Hydropower Limiting Factors** | | | | | |
| Habitat Quantity (Access) | Bonneville Dam | All | | | Secondary for Upper Gorge/White Salmon and Upper Gorge/Hood adults and juveniles |
| Habitat Quantity (Inundation) | Bonneville Dam | All | | | Secondary for Upper Gorge/Hood and Upper Gorge/White Salmon juveniles[16] |
| Habitat Quantity (Access) | Tributary Dams | All | | Primary for Upper Cowlitz, North Fork Lewis, Cispus, and Tilton adults and juveniles; secondary for Clackamas juveniles | Primary for Upper Gorge/White Salmon adults and juveniles; secondary for Upper Gorge/Hood |

unclear.

[16] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to coho salmon as a result of inundation. Based on spawning habitat preferences, it is likely that the impacts of inundation were greatest on fall Chinook and chum salmon.

**Table 6-5**

*Baseline Limiting Factors and Threats Affecting LCR Coho Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast | Cascade | Gorge |
|---|---|---|---|---|---|
| | | | | | adults and juveniles |
| **Harvest Limiting Factors** | | | | | |
| Direct Mortality | Fisheries | A,D | Primary for adults in all populations | | |
| **Hatchery Limiting Factors** | | | | | |
| Food[17] | Smolts from all Columbia Basin hatcheries competing for food and space in the estuary | All | Secondary for juveniles in all populations | | |
| Population Diversity | Stray hatchery fish interbreeding with wild fish | A,P,D | Secondary for Clatskanie adults; primary for adults in all other populations except Scappoose | Secondary for Coweeman, Lewis(N&E), and Salmon Creek adults; primary for adults in all other populations except Sandy | Primary for adults in all populations |
| **Predation Limiting Factors** | | | | | |
| Direct Mortality | Land use | A,P,D | Secondary for juveniles in all populations | | |
| Direct Mortality | Dams | A,P,D | | | Secondary for Upper Gorge/Hood and Upper Gorge/White Salmon adults |

### 6.4.1 Tributary Habitat Limiting Factors

Impaired side channel and wetland conditions and degraded floodplain habitat have significant negative impacts on juvenile coho salmon throughout the ESU and are identified as primary limiting factors for all populations. Degraded riparian conditions also are a primary limiting factor for juveniles and adults of all populations within the ESU, as are channel structure and form issues. Extensive channelization, diking, wetland conversion, stream clearing, and, in some subbasins, gravel extraction have severed access to historically productive habitats, simplified many remaining tributary habitats, and weakened the watershed processes that once created healthy ecosystems. In

[17] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

addition, the lack of large woody debris and appropriately sized gravel has significantly reduced the amount of suitable spawning and rearing habitat.

Sediment conditions (affecting egg to fry survival) are identified as a primary limiting factor for all Washington populations and a secondary limiting factor for the Oregon portion of the ESU.[18] The high density of forest and rural roads throughout the Lower Columbia subdomain leads to an abundance of fine sediment in tributary streams that covers spawning gravel and increases turbidity. Water quantity issues related to withdrawals or to land uses that alter hydrology have been identified as either primary or secondary for all coho salmon populations. In addition, water quality—specifically, elevated water temperature, generally brought about through land uses, lack of functional riparian habitat, and water withdrawals—is a secondary limiting factor for all populations except the Lower Gorge.[19]

In the Coast stratum, tributary habitat limiting factors are generally the same as those described for the ESU and are attributable largely to past and current land uses in Coast-stratum watersheds. Private and state forest land used for timber harvest predominates in the upper reaches of these watersheds, while lower reaches are mostly in agricultural and rural residential use and have been extensively modified by bank stabilization, levees, and tide gates. Water quantity issues related to withdrawals or to land uses that alter hydrology are identified as a primary limiting factor for winter parr in Youngs Bay and Big Creek and as secondary for all other Coast-stratum populations.

Habitat limiting factors in the Cascade stratum are generally the same as those described for the ESU. Altered hydrology and flow timing are identified as a primary limiting factor for the Tilton, Kalama, and Washougal populations and a secondary limiting factor for the other Cascade-stratum populations. Land uses that have led to these conditions include forest management and timber harvest, agriculture, urban and rural residential development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development, especially in the Salmon Creek and lower Clackamas subbasins. The Oregon management unit plan notes that in the Clackamas, high water temperatures are attributed in part to hydropower reservoirs.

A unique issue in the Cascade stratum is legacy effects in the Toutle subbasin of the 1980 Mount St. Helens eruption. The North Fork Toutle in particular was heavily affected by sedimentation from the eruption. A sediment retention structure was constructed on the North Fork Toutle in an attempt to prevent continued severe sedimentation of stream

[18] This distinction likely is an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in sediment conditions in tributary streams or their effects on coho populations.

[19] For the Upper Gorge/White Salmon population, water temperature in the mainstem White Salmon River is at or near optimum levels for salmonids. Maximum temperature within the expected range of anadromous fish within the White Salmon subbasin meets Washington state water quality standards, with the exception of Rattlesnake Creek. Rattlesnake Creek is a significant habitat area where temperature approaches lethal levels in some locations during some years (NMFS 2013).

channels and associated flood conveyance, transportation, and habitat degradation problems. The structure currently blocks access to as many as 50 miles of habitat for anadromous fish. Although fish are transported around the structure via a trap and haul system, it remains a source of chronic fine sediment to the lower river; this reduces habitat quality and has interfered with fish collection at its base.

In the Gorge stratum, habitat limiting factors are generally the same as those described for the ESU and result largely from past and current land uses. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater reaches of the Gorge subbasins, while the lower mainstem and tributary reaches are characterized by transportation and rural residential land uses, with some urban development. Water quantity issues caused by irrigation withdrawals are a primary limiting factor for the Upper Gorge/Hood population and a secondary limiting factor for the other populations. Highway and railroad transportation corridors run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes. For the Upper Gorge populations, inundation of historical habitat by Bonneville Reservoir also is a limiting factor.[20] In addition, Laurance Lake Dam, operated by the Middle Fork Irrigation District, blocks access to coho salmon habitat in the Hood subbasin and is identified as a secondary limiting factor.

Habitat within the White Salmon subbasin was altered by the removal of Condit Dam (breaching occurred in October 2011 and full removal in September 2012). Alterations include near-term negative effects from sediment release and scouring. Scientists and managers expect long-term positive effects as the result of restoration of natural flow regimes and sediment transport, but monitoring is needed to evaluate habitat and fish response to dam removal, and additional assessment of habitat limiting factors will be needed to refine understanding of limiting factors.

### 6.4.2 Estuary Habitat Limiting Factors[21]

As stream-type fish, coho salmon spend less time in the Columbia River estuary and plume than do ocean-type salmon such as fall Chinook, yet estuary habitat conditions nevertheless play an important role in the survival of coho salmon juveniles, particularly those displaying less dominant life history strategies. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all

[20] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to coho salmon as a result of inundation. Based on spawning habitat preferences, it is likely that the impacts of inundation were greatest on fall Chinook and chum salmon.

[21] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 6-5 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River coho salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, also are a primary limiting factor for juveniles from all populations. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor.

Lack of access to peripheral and transitional habitats, such as side channels and wetlands, is a secondary limiting factor for juveniles from all populations, with access being impaired by land uses—including the transportation corridor—and by flow alterations caused by mainstem dams. Other secondary limiting factors in the estuary that affect all coho salmon populations are exposure to toxic contaminants (from urban, industrial, and agricultural sources) and elevated late summer and fall water temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs.[22] Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations.[23] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

### 6.4.3 Hydropower Limiting Factors

The severity of dam-related impacts on coho salmon populations varies throughout the ESU. Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River coho salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 6.4.2).[24] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Although the management unit recovery plans identified temperature impacts of the

[22] Although the management unit plans identified temperature impacts in the estuary as a secondary limiting factor for juveniles in all populations, the timing of juvenile coho salmon migration raises questions about the significance of this limiting factor; see Section 6.4.3.

[23] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[24] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

hydropower system as a secondary limiting factor for all juvenile coho salmon, migration of juvenile coho salmon peaks in mid-April through mid-July. Thus, it is unlikely that elevated mainstem temperatures are having a significant impact on this currently dominant coho salmon life history type. However, some coho salmon juveniles may be present year-round in the estuary (Dawley et al. 1986, McCabe et al. 1986, Roegner et al. 2004, Bottom et al. 2008, cited in Figure 2.2 of Carter et al. 2009). In addition, if recovery is successful in achieving more diverse life-history patterns for coho salmon, it is possible that temperature impacts of the hydropower system could become more significant in localized areas. For the Upper Gorge/Hood and Upper Gorge/White Salmon populations, which spawn above Bonneville Dam, passage issues at Bonneville and inundation of historical spawning habitat by Bonneville Reservoir are identified as secondary limiting factors.[25]

The effects of tributary dams vary by stratum. There are no tributary hydropower dams in the Coast stratum. In the Cascade stratum, tributary hydropower facilities are a primary limiting factor in the Cowlitz subbasin (for the Upper Cowlitz, Cispus, and Tilton populations, but not for the Lower Cowlitz population) and in the Lewis subbasin (for the North Fork Lewis population). Tributary hydropower facilities are a secondary limiting factor for the Clackamas population, impairing downstream passage of juveniles. Tributary hydropower was not identified as a limiting factor in the Sandy subbasin (the PGE Bull Run Hydroelectric Project, which consisted of Marmot Dam and the Little Sandy diversion dam, was removed in 2007-2008). There are no tributary hydropower facilities in the Coweeman, Toutle, Kalama, East Fork Lewis, Salmon Creek, or Washougal subbasins.[26]

In the Gorge stratum, the presence of Condit Dam was identified as a primary limiting factor for the Upper Gorge/White Salmon population. (The dam was breached in October 2011 and completely removed in September 2012, so this limiting factor has now been addressed.) Powerdale Dam on the Hood River was identified as a secondary limiting factor for adult and juvenile passage but was removed in 2010. Tributary hydropower is not a limiting factor for the Lower Gorge population.

### 6.4.4 Harvest Limiting Factors

Harvest-related mortality is identified as a primary limiting factor for all populations within the ESU and occurs as a result of direct and incidental mortality of natural-origin fish in ocean fisheries, Columbia River recreational fisheries, and commercial gillnet fisheries. The harvest targets hatchery-origin fish, which make up the vast majority of coho salmon returning to the Columbia River (Ford 2011). For the period from 1970 to 1993, harvest rates averaged 82 percent (NMFS 2008c). Since 2005, when NMFS listed Lower Columbia River coho salmon, harvest impacts have been reduced through measures such as mark-selective fisheries and time and area closures in both ocean and in-river fisheries, such that exploitation rates on natural-origin Lower Columbia River

[25] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to coho salmon as a result of inundation. Based on spawning habitat preferences, it is likely that the impacts of inundation were greatest on fall Chinook and chum salmon.
[26] However, the North Fork Toutle sediment retention structure currently blocks access to as many as 50 miles of habitat for anadromous fish.

coho salmon have averaged 16 percent.[27] However, some populations experience higher impacts. ODFW estimated that harvest impacts on natural- and hatchery-origin fish from the Youngs Bay and Big Creek populations are as high as 90 percent and 70 percent, respectively, because of terminal fisheries that target hatchery-origin returns to these off-mainstem areas. Some additional harvest affects the populations that pass Bonneville Dam as a result of tribal fisheries in Zone 6.[28] Although harvest has been reduced substantially in recent years, recovery efforts will continue to focus on refinements in harvest management.

### 6.4.5 Hatchery-Related Limiting Factors

From 2005 to 2009, an average of approximately 13 million hatchery coho salmon were released per year in the lower Columbia basin (Ford 2011). Additional hatchery coho salmon are released upstream in the Columbia Basin with potential effects on Lower Columbia River coho salmon through straying and competition and predation in the lower mainstem and estuary. Although this production is reduced from the peak in the late 1980s, legacy effects of hatchery fish and current hatchery production continue to pose a significant threat to Lower Columbia River coho salmon. It is likely that most coho salmon spawning naturally in the lower Columbia River are of hatchery origin. Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish are a primary limiting factor for the majority of the populations in the ESU and a secondary limiting factor for all other populations except the Scappoose and Sandy. Hatchery straying, combined with past stock transfers, has likely reduced genetic diversity within and among Lower Columbia River coho salmon populations. This, combined with the small number of populations with significant natural production, has resulted in reduced diversity within the ESU. Population productivity, abundance, and resilience has likewise declined as a result of the influence of hatchery-origin fish.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

### 6.4.6 Predation Limiting Factors

Direct mortality from predation is a secondary limiting factor for all coho salmon populations. Anthropogenic changes to habitat structure have led to increased predation by Caspian terns, double-crested cormorants, and various other seabird species in the

[27] Fishery impact rates for LCR coho are based on data for the Clackamas and Sandy populations, but because of differences in ocean distribution among populations, there is uncertainty about whether this impact rate applies to all populations.

[28] The mainstem Columbia River is divided into management areas (i.e., zones) in order to manage harvest under the *U.S. v. Oregon* agreement. Zone 6 extends from Bonneville Dam upstream to McNary Dam.

Columbia River estuary and plume. Coho salmon, particularly those spawning above Bonneville Dam, also are subject to predation by non-salmonid fish (primarily pikeminnows above and below the dam but also walleye and smallmouth bass in the reservoir).

## 6.5 Baseline Threat Impacts and Reduction Targets

Table 6-6 shows the estimated impact on each Lower Columbia River coho salmon population resulting from potentially manageable threats, organized into six categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. The table also shows the overall percentage improvement that is needed to achieve the target impacts and corresponding population status.[29] These cumulative values across all threat categories (both baseline and target) are multiplicative rather than additive. Both the Oregon and Washington management unit plans use cumulative survivals across threat categories to illustrate the overall level of improvement needed. Each plan assumes that there is a direct proportional relationship between the projected changes in cumulative survival and the required changes in natural-origin spawner abundance and productivity. For populations where the survival improvement needed is larger than 500 percent, Table 6-6 does not report the exact value, in part because the value is highly uncertain.[30]

As an example, the baseline status of the Grays/Chinook subbasin coho population, circa 1999, has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 94.6 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 5.4 percent of the historical potential with no human impact. Tributary habitat, harvest, and hatchery impacts each accounted for reductions in population productivity of 50 percent or more, with corresponding reductions in abundance, spatial structure, and diversity. The Washington management unit plan identifies a recovery strategy involving significant reductions in the impact of several threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 70 percent to 40 percent (i.e., an approximately 100 percent improvement relative to

[29] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: $[(1\text{-}Cumulative_{Target})\text{-}(1\text{-}Cumulative_{Baseline})]/[1\text{-}Cumulative_{Baseline}] \times 100$. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

[30] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 94.6 percent at baseline to 74.7 percent at the target status. This change would translate into a 370 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for Washington populations reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for Oregon populations reflect conditions through 2004. Dam impacts for Washington populations reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for Oregon populations, the estimates of impacts in the "Dams" column of Table 6-6 reflect direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for Washington populations were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); Oregon recovery planners estimated that hatchery impacts were equivalent to the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting a concern for both genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 6-6 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 6-6 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 6-6 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 6-6 reflect policy decisions and the methodologies and assumptions used by the different recovery planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of coho exposed to

that particular category of threats, whether or not they are exposed to threats in the other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[31] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 6-6, loss and degradation of tributary habitat are the single largest threat to most coho salmon populations—and where the greatest gains in viability are expected to be achieved. Notable exceptions are the Clackamas, Upper Cowlitz, and Cispus populations. For the Clackamas population, protection of existing well-functioning habitat and reductions in hatchery impacts will play a key role in achieving the target status. The Upper Cowlitz and Cispus populations are projected to benefit greatly from hatchery reintroduction programs and dam passage improvements designed to restore their access to key historical spawning and rearing habitats. However, significant tributary habitat protection and restoration efforts also will be necessary for these populations. In most cases, population recovery objectives cannot be achieved without substantial improvements in habitat, even when the impacts of other non-habitat threats are practically eliminated.

Harvest and hatchery effects have been a significant threat to most Lower Columbia River coho salmon populations. Although recent actions have substantially reduced coho salmon harvest levels from baseline conditions, further refinements in harvest management are still needed. Hatchery impacts remain significant for many populations, including the Youngs Bay, Grays/Chinook, Big Creek, Elochoman, and Mill/Abernathy/Germany populations in the Coast stratum; the Upper Cowlitz, Cispus, Washougal, and, to a lesser degree, the Clackamas populations in the Cascade stratum; and all Gorge-stratum populations. Threat reductions associated with estuary habitat improvements and predation management are needed for recovery and will benefit every Lower Columbia River coho salmon population; however, net reductions targeted in these threat categories are smaller than those for tributary habitat, harvest, hatcheries, and, in some cases, hydropower because for most populations the impacts of estuarine and predation threats are less.

Several populations designated as primary are targeted for significant reductions in almost every threat category. These include the Grays/Chinook, Elochoman, Upper Cowlitz and Cispus, Lower Gorge, Upper Gorge/White Salmon, and Upper Gorge/Hood populations. However, Oregon notes in its management unit plan that the tributary habitat and hatchery-related threat reductions targeted for the Upper Gorge/Hood population probably are unattainable. (See Sections 6.3 and 6.7 for

[31] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

additional discussion of issues related to the feasibility of achieving abundance and productivity targets for the Upper Gorge/Hood population.)

More information on threat reduction scenarios, including descriptions of the methodologies used to determine baseline and target impacts, is available in the management unit plans (ODFW 2010, pp. 151-177 and LCFRB 2010a, pp. 4-30 through 4-33, and 6-49 through 6-52).

**Table 6-6**

*Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Coho Salmon Populations*

| Population | Impacts at Baseline[32] | | | | | | | Impacts at Target | | | | | | | % Survival Improvement Needed[40] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T.Hab[33] | Est[34] | Dams[35] | Harv[36] | Hat[37] | Pred[38] | Cumulative[39] | T.Hab | Est | Dams | Harv | Hat | Pred | Cumulative | |
| **Coast** | | | | | | | | | | | | | | | |
| Youngs Bay (OR) | 0.98 | 0.10 | 0.00 | 0.90 | 0.86 | 0.06 | 0.9998 | 0.97 | 0.08 | 0.00 | 0.90 | 0.86 | 0.03 | 0.9996 | 60 |

[32] Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

[33] Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

[34] Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

[35] Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

[36] Includes direct and indirect mortality.

[37] Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

[38] Includes the aggregate predation rate in the mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

[39] Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$. Minor differences from numbers in ODFW (2010) are due to rounding.

[40] Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target). For most populations this was calculated using the following equation: $[(1-\text{Cumulative}_{\text{Target}})-(1-\text{Cumulative}_{\text{Baseline}})]/[1-\text{Cumulative}_{\text{Baseline}}] \times 100$. For some Washington populations (Mill/Abernathy/Germany, Lower Cowlitz, Kalama, Upper Gorge), this equation yields a different result than that reported in LCFRB (2010a) because, for populations that have a very low probability of persistence and require very large improvements, the Washington management unit plan limited threat-specific reductions to 50 percent of the current impact as interim targets until the population response to improvements can be accurately gauged. For those populations, the numbers reported in this table are consistent with LCFRB (2010a) rather than with the aforementioned equation. In addition, these cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts. For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 6.5. For Oregon populations designated as stabilizing (Youngs Bay and Big Creek), a survival improvement is shown because of improvements that are expected in tributary habitat, estuary conditions, and predation.

## Table 6-6

*Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Coho Salmon Populations*

| Population | Impacts at Baseline[32] | | | | | | | Impacts at Target | | | | | | | % Survival Improvement Needed[40] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T.Hab[33] | Est[34] | Dams[35] | Harv[36] | Hat[37] | Pred[38] | Cumulative[39] | T.Hab | Est | Dams | Harv | Hat | Pred | Cumulative | |
| Grays/Chinook (WA) | 0.70 | 0.16 | 0.00 | 0.50 | 0.50 | 0.14 | 0.9458 | 0.40 | 0.09 | 0.00 | 0.29 | 0.29 | 0.08 | 0.7468 | 370 |
| Big Creek (OR) | 0.98 | 0.10 | 0.00 | 0.70 | 0.86 | 0.06 | 0.9993 | 0.97 | 0.08 | 0.00 | 0.70 | 0.86 | 0.03 | 0.9989 | 60 |
| Eloch/Skam (WA) | 0.60 | 0.16 | 0.00 | 0.50 | 0.50 | 0.14 | 0.9278 | 0.42 | 0.11 | 0.00 | 0.35 | 0.35 | 0.10 | 0.8037 | 170 |
| Clatskanie (OR) | 0.83 | 0.10 | 0.00 | 0.35 | 0.13 | 0.06 | 0.9187 | 0.68 | 0.08 | 0.00 | 0.25 | 0.10 | 0.04 | 0.8092 | 140 |
| Mill/Ab/Germ (WA) | 0.50 | 0.16 | 0.00 | 0.50 | 0.50 | 0.15 | 0.9108 | 0.25 | 0.08 | 0.00 | 0.25 | 0.25 | 0.08 | 0.6429 | >500 |
| Scappoose (OR) | 0.83 | 0.10 | 0.00 | 0.35 | 0.05 | 0.06 | 0.9112 | 0.77 | 0.08 | 0.00 | 0.25 | 0.05 | 0.04 | 0.8553 | 60 |
| **Cascade** | | | | | | | | | | | | | | | |
| Lower Cowlitz (WA) | 0.70 | 0.16 | 0.00 | 0.50 | 0.50 | 0.15 | 0.9465 | 0.58 | 0.13 | 0.00 | 0.42 | 0.45 | 0.13 | 0.8986 | 100 |
| Upper Cowlitz (WA) | 0.40 | 0.16 | 1.00 | 0.50 | 0.50 | 0.15 | 1.00 | 0.20 | 0.08 | 0.50 | 0.25 | 0.25 | 0.08 | 0.8096 | >500 |
| Cispus (WA) | 0.50 | 0.16 | 1.00 | 0.50 | 0.50 | 0.15 | 1.00 | 0.25 | 0.08 | 0.50 | 0.25 | 0.25 | 0.08 | 0.82 | >500 |
| Tilton (WA) | 0.95 | 0.16 | 1.00 | 0.50 | 0.50 | 0.15 | 1.00 | 0.95 | 0.16 | 1.00 | 0.50 | 0.50 | 0.15 | 1.00 | 0[41] |
| SF Toutle (WA) | 0.90 | 0.16 | 0.00 | 0.50 | 0.50 | 0.15 | 0.9822 | 0.79 | 0.14 | 0.00 | 0.44 | 0.44 | 0.13 | 0.9507 | 180 |
| NF Toutle (WA) | 0.90 | 0.16 | 0.00 | 0.50 | 0.50 | 0.15 | 0.9822 | 0.79 | 0.14 | 0.00 | 0.44 | 0.44 | 0.13 | 0.9507 | 180 |
| Coweeman (WA) | 0.80 | 0.16 | 0.00 | 0.50 | 0.20 | 0.15 | 0.9429 | 0.62 | 0.12 | 0.00 | 0.39 | 0.15 | 0.12 | 0.8474 | 170 |
| Kalama (WA) | 0.70 | 0.16 | 0.00 | 0.50 | 0.50 | 0.15 | 0.9465 | 0.56 | 0.12 | 0.00 | 0.40 | 0.40 | 0.12 | 0.8773 | >500 |
| NF Lewis (WA) | 0.40 | 0.15 | 0.85 | 0.50 | 0.24 | 0.16 | 0.9756 | 0.38 | 0.14 | 0.80 | 0.47 | 0.22 | 0.15 | 0.9625 | 50 |
| EF Lewis (WA) | 0.80 | 0.15 | 0.00 | 0.50 | 0.21 | 0.16 | 0.9436 | 0.40 | 0.08 | 0.00 | 0.25 | 0.11 | 0.08 | 0.6610 | >500 |
| Salmon Creek (WA) | 0.90 | 0.15 | 0.00 | 0.50 | 0.50 | 0.16 | 0.9822 | 0.90 | 0.15 | 0.00 | 0.50 | 0.50 | 0.16 | 0.9822 | 0 |
| Clackamas (OR) | 0.62 | 0.10 | 0.08 | 0.35 | 0.35 | 0.06 | 0.8750 | 0.61 | 0.08 | 0.06 | 0.25 | 0.10 | 0.04 | 0.7814 | 70 |
| Sandy (OR) | 0.83 | 0.10 | 0.04 | 0.35 | 0.09 | 0.06 | 0.9183 | 0.52 | 0.08 | 0.00 | 0.25 | 0.09 | 0.04 | 0.6948 | 250 |

[41] The Upper Cowltiz, Cispus, and Tilton populations require improvements in every threat category. However, given that hydropower impacts are 100 percent for these populations, they will not benefit from improvements in the other threat categories until some degree of passage is restored. Although passage improvements alone will not lead to recovery, how successful passage improvements are will greatly influence how much improvement is needed in the other threat categories. In addition, the formula for percent survival improvement for these populations was modified to account for the 100 percent hydropower impacts (i.e., to avoid having to divide by zero).

## Table 6-6

*Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Coho Salmon Populations*

| Population | Impacts at Baseline[32] | | | | | | | Impacts at Target | | | | | | | % Survival Improve-ment Needed[40] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T.Hab[33] | Est[34] | Dams[35] | Harv[36] | Hat[37] | Pred[38] | Cumul-ative[39] | T.Hab | Est | Dams | Harv | Hat | Pred | Cumul-ative | |
| Washougal (WA) | 0.80 | 0.15 | 0.00 | 0.50 | 0.50 | 0.16 | 0.9643 | 0.40 | 0.08 | 0.00 | 0.25 | 0.25 | 0.08 | 0.7143 | >500 |
| **Gorge** | | | | | | | | | | | | | | | |
| L Gorge — WA portion | 0.50 | 0.15 | 0.00 | 0.50 | 0.50 | 0.16 | 0.9108 | 0.20 | 0.06 | 0.00 | 0.20 | 0.20 | 0.07 | 0.5524 | 400 |
| L Gorge — OR portion | 0.95 | 0.10 | 0.00 | 0.35 | 0.80 | 0.06 | 0.9945 | 0.63 | 0.08 | 0.00 | 0.25 | 0.10 | 0.04 | 0.8162 | >500 |
| U Gorge/White Salmon (WA)[42] | 0.50 | 0.14 | 0.06 | 0.50 | 0.75 | 0.19 | 0.9591 | 0.31 | 0.09 | 0.04 | 0.31 | 0.46 | 0.12 | 0.7475 | >400 |
| U Gorge/Hood (OR)[43] | 0.94 | 0.10 | 0.27 | 0.35 | 0.80 | 0.07 | 0.9952 | 0.08 | 0.08 | 0.23 | 0.05 | 0.00 | 0.05 | 0.4412 | >500 |

[42] Baseline and target impacts for the Upper Gorge/White Salmon population are from LCFRB (2010a).

[43] Oregon's analysis indicates a low probability of meeting the delisting objective of high viability persistence probability for this population.

## 6.6 ESU Recovery Strategy for LCR Coho Salmon

This section describes the recovery strategy for Lower Columbia River coho salmon. A general summary of the ESU-level strategy is presented first. This is followed by subsections on each of the threat categories and critical uncertainties that pertain to the strategy. Where appropriate, stratum-specific strategies are described for each threat category.

### 6.6.1 Strategy Summary

The ESU recovery strategy for coho salmon involves improvements in all threat categories to increase abundance, productivity, diversity, and spatial structure to the point that the Coast, Cascade, and Gorge strata are restored to a high probability of persistence. The ESU recovery strategy has seven main elements:

1. Protect and improve populations that have a clear record of continuous natural spawning and are likely to retain local adaptation (the Clackamas and Sandy), along with populations where there is documented natural production (the Clatskanie, Scappoose, and Mill/Abernathy/Germany).

2. Fill information gaps regarding the extent of natural production in other populations, and focus additional recovery efforts on populations that have the greatest prospects for improvement.

3. Protect existing high-functioning habitat for all populations.

4. Restore tributary habitat (particularly overwintering habitat) to the point that each subbasin can support coho salmon at the target status for that population. In most subbasins this will mean having adequate habitat to support a viable population.

5. Reduce hatchery impacts on natural-origin fish so that impacts are consistent with the target status of each population. (The Grays/Chinook, Elochoman/Skamokawa, Mill/Abernathy/Germany, Clatskanie, Clackamas, Washougal, and Gorge-stratum populations are targeted for large reductions in hatchery impacts.)

6. Refine harvest management so that impacts are consistent with population and overall ESU recovery goals.

7. Reestablish naturally spawning populations above tributary dams on the Cowlitz and North Fork Lewis rivers by improving passage at dams and continuing to reintroduce coho salmon in these mid- to high-elevation habitats.

Very large improvements are needed in the persistence probability of most coho salmon populations if the ESU is to achieve recovery. (See Table 6-4 for the target status for each coho salmon population and Figure 6-3 for the gaps between baseline and target status.)

The recovery strategy for Lower Columbia River coho salmon is a long-term, "all-H" approach in which plan implementers begin work on all of the elements described above immediately and implement actions associated with each of the six threat categories

simultaneously.[44] As part of a series of 3- to 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation). Recovery will require improvements in every threat category, even those improvements in Table 6-6 that are relatively small. Substantial actions are needed to improve tributary habitat and reduce the effects of hatcheries, harvest, and hydropower; without improvements in all of these threat categories, the benefits of actions in any individual sector are unlikely to be fully realized and the expected threat reductions will not be achieved.

Immediate implementation of certain actions is expected to reduce short-term population risk relatively quickly. Examples include reducing harvest impacts (this has already begun), providing access to blocked habitat, and carrying out site-specific habitat restoration to provide crucial overwintering habitat. Hatchery actions are needed immediately to begin reducing the influence of hatchery-origin fish on natural populations; over the long term, the type and extent of hatchery actions will be adjusted based on the results of new, more extensive population monitoring. The benefits of some actions, such as restoring riparian conditions to improve watershed function, will not be felt for years or decades after implementation. These actions also must be begun as soon as possible so that adequate habitat is in place to support increasing and eventually viable coho salmon populations. Recovery also will require contributions from estuary habitat and predation management actions; however, for stream-type fish such as coho salmon, these gains are expected to be less than those from coordinated efforts to address tributary habitat, hatchery, harvest, and hydropower impacts. In addition, substantial increases are needed in the monitoring of coho salmon spawner abundance, the proportion of hatchery-origin spawners, and fishery impacts in order to fill information gaps, especially in Washington.

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013).

### 6.6.2 Tributary Habitat Strategy

Coho salmon will benefit from the regional tributary habitat strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific projects that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Because the lack of complex overwintering habitat is a primary limiting factor for coho salmon, an immediate priority is to implement actions to increase off-channel, side-channel, and floodplain habitat in a network of high- and low-elevation tributary and Columbia River floodplain locations. Improving riparian cover and

[44] In fact, implementation of recovery actions to reduce threats in each category is already under way, although the scale of effort is less than that called for in this recovery plan.

recruitment of large wood to streams also will be a priority. The subsections below summarize additional, stratum-specific tributary habitat strategies for coho salmon.

#### *6.6.2.1 Coast-Stratum Tributary Habitat Strategies*

In implementing the Lower Columbia River coho salmon tributary habitat strategy in the Coast stratum, considerations include the following:

- Upland areas are predominantly state and private timber land; these lands must be managed to protect and restore watershed processes.

- Lowland areas are primarily in agricultural or rural residential use. These areas have been extensively modified by dikes, levees, bank stabilization, and tide gates; efforts to protect and restore habitat complexity will be priorities here.

- Sediment source analyses and implementation of actions to reduce sediment will be needed in most Coast stratum tributaries.

In addition to the actions described as part of the regional strategy for tributary habitat, the Washington management unit plan calls for restoring passage at culverts and other artificial barriers in the Elochoman subbasin; this would restore access to as many as 10 miles of habitat for coho salmon (LCFRB 2010a, Volume II). The Oregon management unit plan identifies a need to investigate whether headwater springs in the Clatskanie and Scappoose are drying up as a result of land management practices (ODFW 2010).

Assuming that the impacts of other threats are reduced to the levels shown in Table 6-6, the scale of tributary habitat improvements needed for Coast-stratum coho salmon ranges from minimal in the Youngs Bay and Big Creek subbasins to increases of 45 to 50 percent in the productive capacity of tributary habitat in the Grays/Chinook and Mill/Abernathy/Germany subbasins, respectively (LCFRB 2010a, ODFW 2010). For Oregon populations, estimates of the number of additional miles of high-quality coho salmon habitat that are needed range from minimal in Youngs Bay and Big Creek to 19 miles and 10 miles in the Clatskanie and Scappoose subbasins, respectively (ODFW 2010).

#### *6.6.2.2 Cascade-Stratum Tributary Habitat Strategies*

In implementing the Lower Columbia River coho salmon tributary habitat strategy in the Cascade stratum, considerations include the following:

- Upper portions of the Upper Cowlitz, Cispus, Tilton, East Fork Lewis, Washougal, Clackamas, and Sandy subbasins are primarily federal forest lands. Continued implementation of the Northwest Forest Plan will be crucial in protecting and restoring coho salmon habitats in these areas.

- State or private forest land predominates in the upper portions of the Coweeman, Toutle, Kalama, North Fork Lewis, and Salmon Creek subbasins. These lands must be managed to protect and restore watershed processes.

- In the lower reaches of most Cascade subbasins, including the Lower Cowlitz, Coweeman, North Fork Lewis, East Fork Lewis, Toutle, Salmon Creek, and Clackamas, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect urban and industrial development, agricultural land, and, in some cases, gravel mining. Restoration in these areas will need to be balanced with the need to protect existing infrastructure and control flood risk.

- This stratum includes the most heavily urbanized areas in the Columbia Basin. Managing the impacts of growth and development on watershed processes and habitat conditions will be key to the protection and improvement of habitat conditions for coho salmon in these areas.

In addition to the actions described as part of the regional strategy for tributary habitat, addressing passage barriers such as culverts will benefit coho salmon by restoring access to habitat in a number of locations, including the Tilton, Cispus, Lower Cowlitz, and Upper Cowlitz subbasins (in some cases, additional assessment is needed to inventory and prioritize these blockages). Addressing sedimentation issues associated with the sediment retention structure will be a priority for the North Fork Toutle subbasin. In the Sandy subbasin, implementation of the city of Portland's Bull Run water supply habitat conservation plan will contribute significantly to the habitat improvements needed to achieve the recovery target.

Assuming that the impacts of other threats are reduced to the levels shown in Table 6-6, the scale of habitat improvements needed for Cascade-stratum coho salmon populations ranges from minimal—for the Tilton and Salmon Creek populations (which, as stabilizing populations are expected to remain at their baseline status of very low probability of persistence)—to a 35 to 50 percent increase in the productive capacity of tributary habitat in the Sandy, Washougal, and East Fork Lewis subbasins. Oregon estimated that, for the Clackamas population, existing habitat is adequate to achieve a very high probability of persistence. For the Sandy population, 37 additional miles of high-quality habitat (or 74 miles of moderate-quality habitat) are needed.

#### *6.6.2.3 Gorge-Stratum Tributary Habitat Strategies*

In implementing the Lower Columbia River coho salmon tributary habitat strategy in the Gorge stratum, considerations include the following:

- Gorge populations occur in watersheds that are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.

- In the lower reaches of most Gorge tributary streams, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development and transportation infrastructure. For the Lower Gorge population, site-specific actions will include addressing or mitigating the impacts of the highway and railroad transportation corridors that run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes.

In addition to the actions described as part of the regional strategy for tributary habitat, for the Upper Gorge/Hood coho salmon population, reduced instream flow from irrigation withdrawals is a primary threat, so actions to identify and implement flow improvements will be important. Improving fish passage at Laurance Lake Dam on the Clear Branch River and at other barriers in the Hood subbasin, such as irrigation diversions and road and railroad crossings, also will benefit the Upper Gorge/Hood population.

In the White Salmon subbasin, the breaching of Condit Dam in October 2011 (full removal was completed in September 2012) created near-term negative effects in the habitat below the dam and the habitat within the footprint of the former reservoir because of sediment release and scouring. Long-term effects are expected to be positive because of restored natural flow and sediment transport regimes. The White Salmon management unit plan outlines four broad tributary habitat strategies: (1) gain information to identify and prioritize habitat actions, (2) when the dam is removed, restore mainstem habitat, (3) protect and conserve natural ecological processes, and (4) improve habitat in upriver reaches (NMFS 2013). In the near-term, evaluating the effects of the dam breaching and removal on habitat and performing additional assessment of habitat limiting factors are high priorities.

Restoring floodplain connectivity and function is called for at locations below Bonneville Dam; however, there is little opportunity to implement floodplain measures above Bonneville Dam because most mainstem floodplain habitat was inundated by Bonneville Reservoir. For this reason, habitat efforts above the dam will rely on other strategies.

Assuming that the impacts of other threats are reduced to the levels shown in Table 6-6, the Washington management unit plan identifies a 60 percent reduction in baseline tributary habitat impacts to meet the recovery target for the Washington portion of the Lower Gorge population and a 38 percent reduction to meet the target for the Upper Gorge/White Salmon population. Oregon calculated a 35 percent reduction in impact (equivalent to an additional 10 miles of high-quality habitat) needed in the Oregon portion of the Lower Gorge population to achieve recovery targets. For the Upper Gorge/Hood population, achieving delisting targets would entail reducing habitat impacts by about 90 percent, or creating 53 additional miles of high-quality habitat. The Oregon planning team believed that 10 miles of additional high-quality habitat is a feasible goal. There is significant uncertainty surrounding the estimate of 53 additional miles of high-quality habitat because of questions about the historical size of the Upper Gorge/Hood population.

### 6.6.3 Estuary Habitat Strategy

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Lower Columbia River coho salmon. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2.) The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a).

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of coho salmon outmigrating from the Columbia River estuary. Oregon and Washington recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for coho salmon populations based on the estuary module and their own approaches to threat reductions (ODFW 2010, pp. 160, 166-173, and Tables 6-5 through 6-12; LCFRB 2010a, p. 2-79, Table 2-16).

### 6.6.4 Hydropower Strategy

The hydropower recovery strategy for Lower Columbia River coho salmon is to address impacts of tributary hydropower dams through implementation of Federal Energy Regulatory Commission (FERC) relicensing agreements and thereby reestablish viable populations in the Upper Cowltiz, Cispus, North Fork Lewis, and White Salmon subbasins; achieve survival gains in the Hood and Clackamas subbasins; maintain the Tilton population at its baseline persistence probability of very low; and address downstream habitat impacts of the operation of some tributary hydropower dams.

The strategy also includes measures to improve passage survival at Bonneville Dam for the Upper Gorge/Hood and Upper Gorge/White Salmon populations and implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. NMFS estimates that survival of Columbia River coho salmon passing Bonneville Dam was 95.1 percent for juveniles from 2002 to 2009 and 96.9 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expects that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will improve juvenile coho salmon survival at Bonneville Dam by less than ½ percent, and that adult survival will be maintained at recent high levels (NMFS 2008a). Consequently, Oregon has not incorporated survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[45] The Washington management unit plan assumes that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement will aid adults and juveniles from all coho salmon populations originating above Bonneville Dam. For more on actions to improve mainstem dam passage, see the regional hydropower strategy in Section 4.3.2.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the

[45] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for coho salmon.

#### *6.6.4.1 Coast-Stratum Hydropower Strategy*

There are no tributary dams in the Coast ecozone, so the hydropower strategy for Coast-stratum coho salmon is to implement the flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations.

#### *6.6.4.2 Cascade-Stratum Hydropower Strategy*

The hydropower strategy for Cascade-stratum coho salmon is to create or improve passage at projects on the Cowlitz and Lewis rivers and to use hatchery reintroduction programs to reestablish viable populations in the Upper Cowlitz and Cispus subbasins and improve the persistence probability of the North Fork Lewis population (the Tilton population, in the Cowlitz system, is not expected to improve above its baseline persistence probability of very low). In addition, the efficiency of downstream passage facilities at hydropower dams in the Clackamas subbasin will be improved. These changes will be implemented under the terms of FERC relicensing agreements completed with (1) Tacoma Power for the Cowlitz River Project (settlement agreement completed in 2000), (2) PacifiCorp and the Cowlitz PUD for the Lewis River Hydroelectric Projects (settlement agreement in 2004), and (3) PGE for the Clackamas River Hydro Project in 2006. Habitat above the dams in these systems is relatively intact, with well-functioning watershed processes and a high percentage of federal land ownership (although the Tilton subbasin contains more development and a higher percentage of non-federal lands than do the Upper Cowlitz, Cispus, and Lewis subbasins). High-elevation habitat may also become increasingly important as lower elevation habitats are affected by changing climate (LCFRB 2010a).

In the Cowlitz subbasin, the hatchery Barrier Dam prevents all volitional passage of anadromous fish above RM 49.5. As of late 2011, coho salmon are collected at the dam, natural-origin fish are separated from hatchery broodstock, and hatchery- and natural-origin fish are transported upstream of Cowlitz Falls dam and released into the Upper Cowlitz and Cispus rivers.[46] Coho salmon smolts are collected at Cowlitz Falls Dam, briefly held in stress-relief ponds, and released into the lower Cowlitz (LCFRB 2010a). Passage at these dams is expected to be improved at some point as part of the 2000 FERC relicensing agreement. Tacoma Power will evaluate fish returns and survival through the reservoirs and assess passage options. Adult passage will be by trap and haul unless certain settlement agreement criteria (fish sorting, productivity, etc.) are met. If met, then passage at Mayfield Dam is likely to be provided through construction of a ladder,

[46] Hatchery coho salmon also are released into the Tilton subbasin to support a fishery.

whereas passage at the much larger Mossyrock Dam will likely be provided by either trap and haul or a tramway.

In the North Fork Lewis subbasin, three dams (Merwin, Yale, and Swift) block passage to the upper North Fork Lewis, beginning with Merwin Dam at RM 20. As part of the 2004 FERC relicensing agreement for these dams, reintroduction of coho salmon into habitat upstream of the three dams is being evaluated and is likely to occur beginning in 2012-2013. The keys to successful reintroduction will be adequate passage of juveniles and adults to and from the upper watershed, hatchery supplementation, and habitat improvements. In addition, hydroregulation on the Lewis River has altered the natural flow regime below Merwin Dam, and the flow regime will be need to be adjusted to provide adequate flows for habitat formation, fish migration, water quality, floodplain connectivity, habitat capacity, and sediment transport. However, floodplain and channel alterations in the lower river will limit the ability to restore the natural flow regime, and flow modifications will need to take place in concert with restoration of lower river floodplain function and with management considerations for Lewis River late-fall Chinook salmon.

In the Clackamas subbasin, there are both upstream and downstream passage facilities at the River Mill-Faraday-North Fork Dam complex operated by PGE. Early-run coho salmon, which are mostly of hatchery origin, also reproduce naturally in lower river tributaries and in the upper Clackamas above North Fork Dam. Clackamas late-run coho salmon are naturally produced fish and spawn mostly above North Fork Dam. As part of the 2006 FERC relicensing agreement, PGE agreed to improve downstream juvenile mortality through the dam complex to 3 percent or less and has already rebuilt the ladder and trap at North Fork Dam.

#### *6.6.4.3 Gorge-Stratum Hydropower Strategy*

Tributary hydropower impacts for the Upper Gorge/White Salmon and Upper Gorge/Hood populations largely have been addressed by the removal of Condit and Powerdale dams, respectively. Condit Dam, on the White Salmon River, was breached by PacifiCorp in October 2011 and, under the terms of a 1999 decommissioning agreement and a 2006 Biological Opinion, was completely removed in September 2012. Removal reopens access to 17.7 miles of historical coho salmon habitat and will allow reestablishment of natural spawning in an area where coho salmon have been extirpated. The strategy calls for 4 to 5 years of monitoring after dam removal to determine whether natural recolonization is occurring through natural straying and then use of a hatchery reintroduction program if needed.

Powerdale Dam, on the Hood River, was operated by PacifiCorp and removed in 2010 under the terms of a settlement agreement reached in 2003. The dam had passage systems in place, but removal is expected to improve access to historical coho salmon spawning and rearing habitat, further improve upstream and downstream survival, and reduce hydropower-related mortality for the Upper Gorge/Hood coho salmon population (ODFW 2010).

Actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will also provide slight improvements in juvenile survival at Bonneville Dam for the two Upper Gorge populations (see the regional hydropower strategy in Section 4.3.2).

### 6.6.5 Harvest Strategy

Managers have implemented substantial reductions in coho salmon harvest impacts, which averaged 82 percent for the period from 1970 to 1993 (NMF 2008c). Since NMFS listed Lower Columbia River coho salmon in 2005, harvest rates have averaged 16 percent. Consistent with the regional harvest strategy (see Section 4.5.2), the Oregon and Washington management unit plans both call for further refinements in harvest management practices so that they are consistent with population and overall ESU recovery goals while also maintaining harvest opportunities that target hatchery coho salmon.

Harvest rates on naturally produced coho salmon currently are established using an abundance-based harvest matrix that considers spawning escapement and marine survival. Annual coho salmon harvest rates are set through the Pacific Fishery Management Council's annual planning process in consultation with NMFS. The matrix is based on the status of the Clackamas and Sandy populations—the only populations within the ESU that were being monitored at the time the matrix was developed, and the two populations believed to be the ESU's strongest. Consequently, the matrix does not adequately consider the effects of harvest on the ESU's weaker populations. All coho salmon recreational fisheries have been mark-selective since 1998. Some commercial ocean fisheries have also been mark-selective in recent years, but mainstem gillnet fisheries currently are not.

The management unit plans envision refinements in coho salmon harvest through (1) replacement or refinement of the existing harvest matrix to ensure that it adequately accounts for weaker components of the ESU, (2) continued use of mark-selective recreational fisheries, and (3) management of mainstem commercial fisheries to minimize impacts to natural-origin coho salmon.[47] In refining the harvest matrix, the objective is to ensure that harvest management is consistent with maintaining trajectories in populations where natural production is beginning to be observed (e.g., the Clatskanie and Scappoose), with the assumption that additional refinements will be evaluated as natural production is documented in additional populations. Managing coho salmon harvest to minimize impacts to natural-origin fish is complicated by uncertainties regarding annual natural-origin spawner abundance and actual harvest impacts on natural-origin fish (in both ocean and mainstem Columbia fisheries). The management unit plans note these uncertainties and highlight the need for improved monitoring of harvest mortality and natural-origin spawner abundance.

In terms of recommended harvest rates, Oregon modeled a harvest rate of 25 percent as a long-term average under an abundance-based framework. The Washington management unit plan recommends a phased harvest strategy involving lower near-term rates to reduce population risks until habitat has improved. Modeling in the

[47] The Youngs Bay and Big Creek populations would continue to experience higher harvest rates to accommodate terminal fisheries targeting hatchery fish in those areas.

Washington management unit plan shows a scenario in which harvest rates would be managed for benchmarks of 8 to 25 percent throughout the first three of multiple 12-year evaluation periods (i.e., from 1999 through 2034). Then, the modeling shows that, assuming that benchmarks for habitat and other improvements have been met, harvest rates could rise (to 15 to 35 percent in the 2035 to 2046 period and to 20 to 50 percent thereafter) (LCFRB 2010a). These modeling results are planning targets and not predictions of future harvest rates; managers will establish future harvest rates based on observed indicators in Lower Columbia River coho salmon populations.

Near-term priorities for implementing this harvest strategy include:

- Obtaining better information on natural-origin and hatchery-origin spawner escapement and better estimates of natural population productivity
- Obtaining a better estimate of harvest impact rates for natural-origin Lower Columbia River coho salmon in ocean and Columbia River mainstem fisheries (and, in particular, addressing uncertainties related to harvest impacts in mainstem fisheries)
- Evaluating and refining harvest strategies for periods of poor ocean conditions and for years when returns are strong
- Incorporating into the matrix a method of managing for weaker stocks that would benefit from harvest reductions
- Developing mark-selective fishing methods that can be used in the commercial mainstem fisheries

#### *6.6.5.1 Coast-Stratum Harvest Strategies*

The ESU-level harvest strategies will reduce harvest impacts on most populations in the Coast stratum. Exceptions are the Youngs Bay and Big Creek populations, which are and will continue to be subject to higher harvest rates than most coho salmon populations because of Select Area fisheries. These fisheries, which are separate from the mainstem Columbia River fisheries, target hatchery coho salmon that return a few weeks earlier than the historical coho salmon run did (ODFW 2010). Under the harvest recovery strategy, the Select Area fisheries will continue, as will the corresponding high harvest impacts on the Youngs Bay and Big Creek populations (estimated at 90 and 70 percent, respectively). ODFW may adjust the end dates for the Youngs Bay and Big Creek fisheries to further reduce impacts to natural-origin coho salmon in those subbasins (ODFW 2010). WDFW also opens fisheries in the Grays to target coho salmon originating in the Deep River net pen program and straying to the Grays.

#### *6.6.5.2 Cascade-Stratum Harvest Strategies*

ESU-level harvest strategies will benefit populations in this stratum. In addition, if the hatchery coho salmon program in the Clackamas subbasin is maintained, ODFW may increase the within-basin harvest rate on those hatchery fish to help reduce pHOS.

#### *6.6.5.3 Gorge-Stratum Harvest Strategies*

ESU-level harvest strategies will benefit populations in this stratum.

### 6.6.6 Hatchery Strategy

The regional hatchery strategy described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River coho salmon. Details of how the hatchery strategy will be implemented in each coho stratum will be developed as part of the transition schedules, but the subsections below provide some information. In instances where the run timings in coho salmon hatchery programs do not correspond to historical run timings, NMFS expects to work with its fish resource co-managers to determine the appropriate implementation strategy relative to historical run timing.

#### *6.6.6.1 Coast-Stratum Hatchery Strategies*

The preliminary intent for hatcheries in the Coast stratum includes maintaining the Youngs Bay and Big Creek subbasins as areas of hatchery production to support Select Area fisheries. Some hatchery coho salmon production from the Clackamas, Sandy, and Lower Gorge populations will be shifted to Youngs Bay to reduce hatchery-origin spawners in those upriver populations. Existing weirs in both Youngs Bay and Big Creek will be used to exclude hatchery-origin fish and create natural-origin spawning areas.[48] The Clatskanie, Scappoose, Elochoman, and Mill/Abernathy/Germany subbasins will remain areas where no hatchery fish are released. If the level of hatchery fish straying from programs in other subbasins to spawn naturally in the Clatskanie and Scappoose systems is found to exceed 10 percent over a 9-year period, then ODFW will consider additional actions to reduce pHOS, including the installation of a weir and trap to sort hatchery fish. In the Grays subbasin, hatcheries will continue to be operated to support coho salmon harvest and potentially to enhance natural production through development of hatchery broodstocks similar to the late-returning historical populations (LCFRB 2010a).

#### *6.6.6.2 Cascade-Stratum Hatchery Strategies*

In the Cascade stratum, hatcheries will be used in the near term to reintroduce coho salmon in the Upper Cowlitz subbasin (Upper Cowlitz, Cispus, and Tilton populations) and North Fork Lewis subbasin (LCFRB 2010a). Hatchery-origin adult coho salmon already are being released upstream of dams to spawn naturally in the Upper Cowlitz, Cispus, and Tilton rivers, and in the North Fork Lewis, hatchery programs will be used to reintroduce coho salmon to the upper Lewis.

The preliminary intent is also that the Coweeman River in Washington will remain an area with no hatchery releases, along with the Clackamas River above North Fork Dam. For the Clackamas population, ODFW intends to meet a pHOS target of 10 percent or less by reducing coho salmon hatchery releases (from 500,000 to 350,000 beginning in

[48] Clackamas coho production was reduced from 500,000 to 350,000 beginning in 2009. Sandy coho production was reduced from 700,000 to 500,000 in 2010, with the difference shifted to Youngs Bay. Lower Gorge releases were reduced from 1.2 million to 725,000 in 2010, with the difference shifted to the lower Columbia.

2009), increasing harvest rates on hatchery coho salmon below North Fork Dam, and operating the trap at Eagle Creek hatchery for longer periods of time if needed. Coho salmon produced at the Eagle Creek hatchery are also used in reintroduction programs in the Yakima and Umatilla subbasins. When the Yakima and Umatilla programs are able to obtain broodstock from coho salmon returning to those subbasins, ODFW expects to work with the U.S. Fish and Wildlife Service (which manages the Eagle Creek hatchery) to explore options for eliminating the in-basin program altogether (ODFW 2010).

WDFW may consider short-term supplementation programs in some Cascade populations to bolster natural fish numbers above critical levels in selected areas until habitat is restored to levels where a population can be self-sustaining (LCFRB 2010a, Vol. II). Hatchery production for fishery enhancement will be the focus of hatchery programs in the Washougal, some programs in the Lower Cowlitz and North Fork Lewis, the North Fork Toutle, the Kalama, the Clackamas, and the Sandy (LCFRB 2010a, ODFW 2010). A weir will be installed in the lower Washougal River to separate hatchery- and natural-origin fish and to control the proportion of hatchery-origin fish on the spawning grounds. An existing weir in the lower Kalama River will be used for the same purpose.

#### *6.6.6.3 Gorge-Stratum Hatchery Strategies*

For the Lower Gorge population, Oregon proposes to reduce pHOS by reducing coho salmon releases from the Bonneville hatchery from 1.2 million to 725,000 (with the difference in production shifted to Youngs Bay) and, possibly, using a trap and weir to separate hatchery-origin adults. Additionally, Oregon proposes discussions with tribes regarding longer acclimation and rearing at tribal release sites; this would increase imprinting to reduce hatchery-origin fish straying into the lower Gorge tributaries (ODFW 2010). Washington may consider a supplementation program for its Lower Gorge tributaries at some point in the future (LCFRB 2010a, Vol. II)

For the Upper Gorge/Hood population, Oregon outlines a strategy to reduce hatchery strays and to evaluate whether a reintroduction program is needed. The primary source of stray hatchery-origin coho salmon in the Hood subbasin is from releases of hatchery coho salmon into the Klickitat and Umatilla subbasins as part of reintroduction programs. Releases into the Umatilla subbasin dropped from 1.5 million to 1 million in 2010. Additional reductions are expected for Klickitat River releases; however, reductions in these programs must be balanced with their intended purpose to support fisheries. Coho produced in tribal hatchery programs in the Klickitat River will also be marked. ODFW also will investigate opportunities to place weirs to trap and sort hatchery fish, but feasibility depends on finding a site where enough fish would be intercepted to achieve management objectives and that would allow for safe and reliable operation at an acceptable cost in a large system such as the Hood (ODFW 2010).

For the Upper Gorge/White Salmon population, coho salmon releases from the Little White Salmon National Fish Hatchery ended in 2004, under an agreement among the parties to U.S. v. Oregon. In the White Salmon subbasin, the White Salmon Working Group, made up of federal, state, and tribal fisheries managers and representatives of PacifiCorp, has recommended monitoring natural coho salmon escapement and

production for 4 to 5 years after Condit Dam is removed.[49] Depending on the results, they will then recommend either proceeding with natural recolonization or with supplementation (perhaps with hatchery juveniles from the Washougal and/or Bonneville/Cascade hatchery or offspring of wild broodstock from the Klickitat or White Salmon rivers) (NMFS 2013).

### 6.6.7 Predation Strategy

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia ESUs, including coho salmon.

### 6.6.8 Critical Uncertainties

Each aspect of the coho salmon recovery strategy has a number of critical uncertainties; in addition, there are critical uncertainties related to the historical structure of coho salmon populations, primarily in the Gorge ecozone. For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to the Lower Columbia River coho salmon recovery strategy include the following:

- Historical role of the Gorge populations and appropriate target persistence probabilities and abundance and productivity targets for those populations
- Current natural-origin and hatchery-origin spawner escapement and productivity
- Relationship of current run timings (early/late) to historical run timings, harvest impacts on specific populations relative to their return timing, and the appropriate harvest strategy in light of this information (particularly the suitability of timing harvest to coincide with the return of the Cowlitz coho salmon population)
- Impact of climate change on freshwater and ocean habitats, including the impact of ocean acidification on the marine food webs on which salmon depend[50]
- Effectiveness of various approaches to developing integrated hatchery/natural populations
- Effectiveness of weirs in achieving pHOS targets
- Feasibility of achieving hatchery production and performance targets and maintaining harvest levels

[49] Condit Dam was breached in October 2011 and completely removed in September 2012.
[50] The impact of climate change is a critical uncertainty for all species addressed in this recovery plan but is particularly pertinent to coho because coho are sensitive to local ocean conditions. See Section 4.7 for additional discussion of the impacts of climate change on Lower Columbia River salmon and steelhead.

- Effective methods of providing adequate downstream passage efficiency for juveniles migrating past tributary dams

- Diversity of coho salmon life history strategies and how much coho salmon displaying less dominant life history strategies use the Columbia River estuary

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10, additional discussion among local recovery planners and NMFS staff will be needed to finalize future research and monitoring priorities for Columbia River coho salmon.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the Lower Columbia Fish Recovery Board completed the *Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above also does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the coho salmon recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

## 6.7 Delisting Criteria Conclusion for LCR Coho Salmon

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Lower Columbia River coho salmon ESU from the Federal List of Endangered and Threatened Wildlife and Plants (that is, to delist the ESU), NMFS must determine that the ESU, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12). The

recovery criteria in this plan (both biological and threats criteria) meet this statutory requirement.

As described in Section 6.3, if the scenario in Table 6-4 were achieved, it would exceed the WLC TRT's viability criteria, particularly in the Cascade stratum (see Table 6-7).[51] Exceeding the criteria in the Cascade stratum was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge stratum, in particular the questions raised by Oregon about the feasibility of meeting the target status for the Upper Gorge/Hood population.

**Table 6-7**
*Coho Salmon Recovery Scenario Scores Relative to WLC TRT's Viability Criteria*

| Species | Number of Primary Populations | | | | | Stratum Average Criteria | | | |
|---|---|---|---|---|---|---|---|---|---|
| Coho | | Coast | Cascade | Gorge | Total | | Coast | Cascade | Gorge |
| | n ≥ high | 4 | 9 | 3 | 16 | Avg. score | 2.29 | 2.39 | 3 |
| | TRT criterion (n ≥ 2) met? | Yes | Yes | Yes | | TRT criterion (avg. ≥ 2.25) met? | Yes | Yes | Yes |

Source: Based on LCFRB (2010a), Table 4-7.

Oregon recovery planners' uncertainty about the feasibility of meeting the recovery target of high persistence probability for the Upper Gorge/Hood population is based in part on questions about the feasibility of meeting the habitat and hatchery threat reduction targets for this population (ODFW 2010) and in part on questions raised by both Oregon and Washington management unit planners regarding Gorge strata and population delineations and the historical role of the Gorge populations (LCFRB 2010a, ODFW 2010). These questions include whether the Gorge populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum.

As discussed in Section 3.2, NMFS has considered the WLC TRT's viability criteria (from McElhany et al. 2003 and 2006 and summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios and population-level goals in the management unit plans, and the questions management unit planners raised regarding the historical role of the Gorge strata.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of an ESU that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the recovery scenario

[51] For example, in the Cascade stratum, nine populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average viability score for all populations in the stratum would be 2.39. As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher.

presented in the management unit plans for Lower Columbia River coho salmon (summarized in Table 3-1 of this recovery plan) and the associated population-level abundance and productivity goals (see Section 6.3) and has concluded that they also adequately describe the characteristics of an ESU that no longer needs the protections of the ESA. NMFS endorses the Lower Columbia River coho salmon recovery scenario and the associated population-level goals in the management unit plans (summarized in Table 3-1 and Section 6.3) as one of multiple possible scenarios consistent with delisting.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and stratum merits further examination. The extent to which compensation in the Cascade stratum is ultimately considered necessary to achieve an acceptably low risk at the ESU level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following delisting criteria for the Lower Columbia River coho salmon ESU. (NMFS has amended the WLC TRT's criteria to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge stratum):

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition. High probability of stratum persistence is defined as:

    a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

    b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

    c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

    A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria described in Section 3.2.2 have been met.

# 7. Lower Columbia River Chinook Salmon

## 7.1 Chinook Salmon Biological Background

### 7.1.1 Life History and Habitat

Lower Columbia River Chinook salmon (*Oncorhynchus tshawytscha*) are classified as spring, fall, or late fall based on when adults return to fresh water. Other life history differences among run types include the timing of spawning, incubation, emergence in freshwater, migration to the ocean, maturation, and return to fresh water. This life history diversity allows different runs of Chinook salmon to use streams as small as 10 feet wide and rivers as large as the mainstem Columbia. Stream characteristics determine the distribution of run types among lower Columbia River streams. Depending on run type, Chinook rear for a few months to a year or more in freshwater streams, rivers, or the estuary before migrating to the ocean in spring, summer, or fall. All runs migrate far into the north Pacific on a multi-year journey along the continental shelf to Alaska before circling back to their river of origin. The spawning run typically includes three or more age classes. Adult Chinook salmon are the largest of the salmon species, and Lower Columbia River fish occasionally reach sizes up to 25 kilograms. Chinook salmon require clean gravels for spawning and pool and side-channel habitats for rearing (see Table 7-1 for freshwater habitat needs). All Chinook salmon die after spawning (LCFRB 2010a).

#### *7.1.1.1 Spring Chinook Salmon Life History*

Lower Columbia River spring Chinook salmon spawn primarily in upstream, higher elevation portions of large subbasins. Adults enter the lower Columbia River from March through June, well in advance of spawning in August and September (see Figure 7-1).

Spring Chinook salmon are "stream-type" salmon that generally rear in the river for a full year. This extended freshwater residency is characteristic of Chinook salmon that inhabit watersheds where temperature and flow conditions provide suitable habitat conditions throughout the year. Most stream-type juveniles emigrate from fresh water as yearlings, typically in the spring of their second year. However, some juveniles from Lower Columbia River spring Chinook salmon populations migrate downstream from their natal tributaries in the fall and early winter into larger rivers, including the mainstem Columbia River, where they are believed to over-winter before outmigrating the next spring as yearling smolts (LCFRB 2010a).

Once spring Chinook salmon leave freshwater, they usually move quickly through the estuary, into coastal waters, and ultimately to the open ocean. Once in the ocean, spring Chinook salmon migrate as far north as the Aleutian Islands and are widely distributed in the open ocean, far from coastal waters. Most remain at sea from 1 to 5 years (more commonly 2 to 4 years) and return to spawn at 3 to 6 years of age (LCFRB 2010a).

**Table 7-1**
*Key Habitat for Fall and Spring Chinook Salmon, by Life Stage*

| Life Stage | Key Habitat Descriptions |
|---|---|
| Spawning | Riffles, tailouts, and the swifter areas in glides containing a mixture of gravel and cobble sizes with flow of sufficient depth for spawning activity |
| Incubation | As for spawning, but with sufficient flow for egg and alevin development |
| Fry Colonization | Shallow, slow-velocity areas within the stream channel, including backwater areas, often associated with stream margins and back eddies and usually in relatively low-gradient reaches. |
| Active Rearing | Relatively slow-water habitat types, often near velocity shears, often associated with relatively low-gradient stream channel reaches, including primary pools, backwaters, tailouts, glides, and beaver ponds. |
| Inactive Rearing | Non-turbulent habitat types, particularly deeper water types within the main channel, but also including slower portions of large cobble riffles. |
| Migrant | All habitat types having sufficient flow for free movement of juvenile migrants. |
| Pre-Spawning Migrant | All habitat types having sufficient flow for free movement of sexually mature adult migrants. |
| Pre-Spawning Holding | Relatively slow, deep-water habitat types typically associated with (or immediately adjacent to) the main channel. |

Source: Adapted from Northwest Power and Conservation Council (2004b).

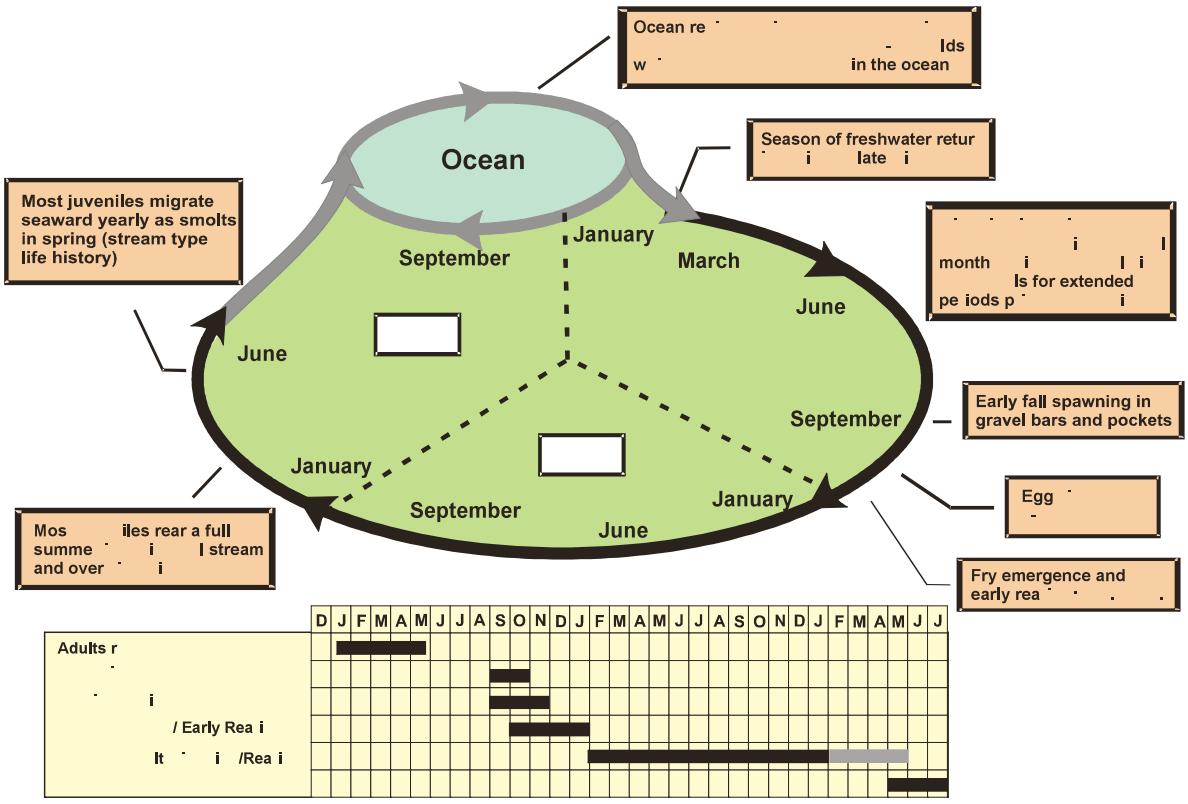


**Figure 7-1.** *Life Cycle of Lower Columbia River Spring Chinook Salmon*

(Source: LCFRB 2010a)

#### *7.1.1.2 Fall Chinook ("Tule") Salmon Life History*

Fall Chinook salmon spawn in moderate-sized streams and large river mainstems, including most tributaries of the lower Columbia River. Most Lower Columbia River fall Chinook salmon enter freshwater from August to September and spawn from late September to November, with peak spawning activity in mid-October (see Figure 7-2). These fish, referred to as "tule" stock, are distinguished by their dark skin coloration and advanced state of maturation at their return to fresh water. Tule fall Chinook salmon populations historically spawned in rivers and streams from the mouth of the Columbia River to the Klickitat River.

Lower Columbia River fall Chinook salmon display an "ocean-type" life history. Juveniles typically begin emigrating downstream as subyearlings at 1 to 4 months of age and enter salt water in late summer or autumn. Juvenile trapping indicates that individual populations display different combinations of two basic temporal patterns: an early fry outmigration downstream into intertidal areas in the early spring, followed by a component that rears for a longer period in natal tributary habitat and outmigrates in late spring/early summer (Cooney and Holzer 2011). Ocean-type juveniles make extensive use of the estuary. Rivers with well-developed estuaries, such as the Columbia, are able to sustain large populations of ocean-type salmon. Subyearling Chinook salmon can be found in the Columbia River estuary during every month of the year. After spending weeks or months rearing in the estuary, Lower Columbia River fall Chinook salmon migrate northward into ocean waters off of Washington, British Columbia, and Southeast Alaska. Most fall Chinook salmon remain at sea from 1 to 5 years (more commonly 3 to 5 years) and return to spawn at 2 to 6 years of age. They return to fresh water in late summer or fall and usually spawn within a few weeks (LCFRB 2010a).

#### *7.1.1.3 Late-Fall ("Bright") Chinook Salmon Life History*

Late-fall Chinook salmon, commonly referred to as "brights," generally return later than tule fall Chinook salmon, are less mature when they enter the Columbia, and spawn later in the year. Late-fall Chinook salmon enter the Columbia River from August to October and spawn from November to January, with peak spawning in mid-November. Late-fall Chinook salmon return to Washington's Lewis River and the Sandy River in Oregon.[1] Late-fall Chinook salmon exhibit a stream-type life history (LCFRB 2010a).

[1] In addition, bright fall Chinook salmon that originate from out-of-ESU hatchery fish spawn in the Columbia River mainstem immediately downstream of Bonneville Dam and in the Wind and White Salmon subbasins; these fish are not part of the Lower Columbia River ESU and are not addressed in this recovery plan. Natural-origin Lower Columbia River bright Chinook are referred to as the "lower river wild" stock in the US v. Oregon process.

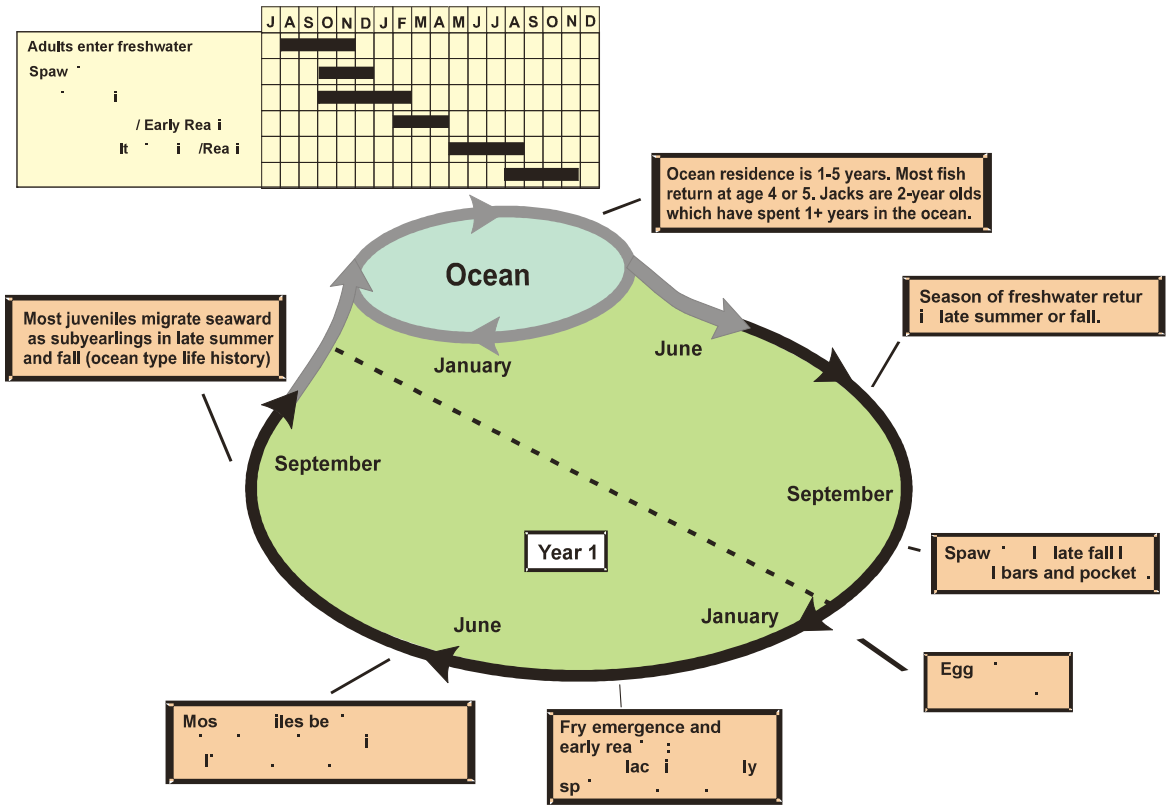


**Figure 7-2.** *Life Cycle of Lower Columbia River Fall Chinook Salmon*

(Source: LCFRB 2010a)

### 7.1.2 Historical Distribution and Population Structure of LCR Chinook Salmon

The WLC TRT identified a total of 32 historical independent populations in this ESU: 21 fall, two late-fall, and nine spring-run populations. Table 7-2 lists these populations and indicates core populations (which historically were highly productive) and genetic legacy populations (which represent important historical genetic diversity). Figures 7-3, 7-4, and 7-5 show the geographical distribution of Lower Columbia River Chinook salmon strata and populations.

Up through 2008, 17 artificial propagation programs produced Chinook salmon considered to be part of this ESU. In 2009, the Elochoman tule fall Chinook salmon program was discontinued, and in 2011, NMFS recommended removing this program from the ESU (76 *Federal Register* 50448). Four new fall Chinook salmon programs have been initiated: Deep River Net-Pen Fall Chinook, Klaskanine Hatchery Fall Chinook, Bonneville Hatchery Tule Fall Chinook, and Little White Salmon National Fish Hatchery Tule Fall Chinook. These programs are changes in release locations for fish produced at, and previously released from, existing hatchery programs that are part of the ESU. In 2011, NMFS recommended including these programs in the ESU (76 *Federal Register* 50448; Jones et al. 2011). Table 7-3 shows the 20 Chinook salmon hatchery programs that currently are included in the ESU. For a list of Chinook salmon hatchery programs not included in the ESU, see Jones (2011).

**Table 7-2**
*Historical LCR Chinook Salmon Populations*

| Stratum | Historical Populations | Core or Genetic Legacy Populations |
|---|---|---|
| Cascade spring | Upper Cowlitz (WA) | Core, genetic legacy |
| | Cispus (WA) | Core |
| | Tilton (WA) | |
| | Toutle (WA) | |
| | Kalama (WA) | |
| | NF Lewis (WA) | Core |
| | Sandy (OR) | Core, genetic legacy |
| Gorge spring | White Salmon (WA) | Core |
| | Hood (OR) | |
| Coast fall | Youngs Bay (OR) | |
| | Grays/Chinook (WA) | |
| | Big Creek (OR) | Core |
| | Elochoman (WA) | Core |
| | Clatskanie (OR) | |
| | Mill (WA) | |
| | Scappoose (OR) | |
| Cascade fall | Lower Cowlitz (WA) | Core |
| | Upper Cowlitz (WA) | |
| | Toutle (WA) | Core |
| | Coweeman (WA) | Genetic legacy |
| | Kalama (WA) | |
| | Lewis (WA) | Genetic legacy |
| | Salmon Creek (WA) | |
| | Clackamas (OR) | Core |
| | Sandy River early (OR) | |
| | Washougal (WA) | |
| Gorge fall | Lower Gorge (WA & OR) | |
| | Upper Gorge (WA & OR) | Core |
| | White Salmon (WA) | Core |
| | Hood (OR) | |
| Cascade late fall | Lewis (WA) | Core, genetic legacy |
| | Sandy (OR) | Core, genetic legacy |

Source: McElhany et al. (2003), Myers et al. (2006).

**Table 7-3**
*Artificial Propagation Programs Included in the LCR Chinook Salmon ESU*

| Run Type | Washington Programs | Oregon Programs |
|---|---|---|
| Spring Chinook | Upper Cowlitz | Sandy River |
| | Cispus | |
| | Friends of the Cowlitz | |
| | Kalama | |
| | Lewis River | |
| | Fish First | |
| Tule Fall Chinook* | Sea Resources | |
| | Cowlitz (Deep River Net-Pen) | Big Creek |
| | | Astoria High School (STEP) |
| | North Fork Toutle | Warrenton High School (STEP) |
| | Kalama | |
| | Washougal | Klaskanine |
| | Spring Creek (Little White Salmon and Bonneville) | |

* The last returns from the Elochoman tule fall Chinook hatchery program are expected in 2013. This program has been part of the ESU in the past but was discontinued in 2009, so it is no longer included in the ESU.

Source: 70 *Federal Register* 37177, 76 *Federal Register* 50448, and Jones (2011).

## 7.2 Baseline Population Status for LCR Chinook Salmon

Populations of Lower Columbia River Chinook salmon have declined substantially from historical levels. Out of the 32 populations that make up this ESU, only the two late-fall runs—the North Fork Lewis and Sandy—are considered viable. Most populations (26 out of 32) have a very low probability of persistence over the next 100 years (and some are extirpated or nearly so (LCFRB 2010a, ODFW 2010, Ford 2011).[2] Five of the six strata fall significantly short of the WLC TRT criteria for viability; one stratum, Cascade late-fall, meets the WLC TRT criteria (see Figures 7-3, 7-4, and 7-5).

Low abundance, poor productivity, losses of spatial structure, and reduced diversity all contribute to the very low persistence probability for most Lower Columbia River

[2] As described in Sections 2.5 and 2.6, the WLC TRT recommended methods for evaluating the status of Lower Columbia River salmon and steelhead populations. The TRT's approach is based on evaluating the population parameters of abundance, productivity, spatial structure, and diversity and then integrating those assessments into an overall assessment of population persistence probability. As also described in Section 5.1, management unit recovery planners evaluated their respective populations' baseline status in a manner generally consistent with the WLC TRT's approach, with the baseline period being either circa 1999 (for Washington populations) or 2006-2008 (for Oregon populations). Unless otherwise noted, NMFS and the management unit planners believe that those assessments accurately reflect the status of the population at that time; the assessments are the basis for the summaries presented here and are consistent with the conclusions of the Northwest Fisheries Science Center in its *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act* (Ford 2011). New information on population status will continue to accumulate over time and will be taken into account as needed to reflect the best available science regarding a population's status.

Chinook salmon populations. Many of the ESU's populations are believed to have very low abundance of natural-origin spawners (100 fish or fewer), which increases genetic and demographic risks. Other populations have higher total abundance, but several of these also have high proportions of hatchery-origin spawners. Particularly for tule fall Chinook salmon populations, poor data quality prevents precise quantification of population abundance and productivity; data quality has been poor because of inadequate spawning surveys and the presence of unmarked hatchery-origin spawners (Ford 2011).3 Spatial structure has been substantially reduced in several populations. Low abundance, past broodstock transfers and other legacy hatchery effects, and ongoing hatchery straying may have reduced genetic diversity within and among Lower Columbia River Chinook salmon populations. Hatchery-origin fish spawning naturally may also have reduced population productivity (LCFRB 2010a, ODFW 2010).

### 7.2.1 Baseline Status of LCR Spring Chinook Salmon

Six out of the nine spring Chinook salmon populations that are part of this ESU are estimated to have a very low probability of persistence (see Figure 7-3). Two—the White Salmon and Hood River populations—are considered extirpated, either because dams have blocked or impeded access to historical spawning habitat and/or because it is assumed that no remnants exist either in a hatchery or in the wild.[4] No spring Chinook salmon population is considered viable at baseline levels.

The very low persistence probabilities (and, in some cases, the likely extirpation) of most spring Chinook salmon populations are a function of losses in abundance, productivity, spatial structure, and diversity. The spatial structure of most spring Chinook salmon populations has been severely reduced by tributary dams that block access to core headwater spawning areas. In areas that remain accessible, distribution has been limited by habitat degradation. The genetic and life history diversity of spring Chinook salmon also has likely been greatly reduced, primarily as a result of population bottlenecks within the natural populations, habitat loss, and hatchery practices. Although hatchery programs are an important conservation tool for spring Chinook populations in some subbasins—primarily the Cowlitz and Lewis, where hatchery programs are serving as genetic reserves for use in reintroduction program—the long-term effects of the high fraction of hatchery-origin spawners in natural production areas is a concern (LCFRB 2010a, ODFW 2010).

[3] Both Oregon and Washington have recently begun efforts to identify and address data gaps, and all hatchery fall Chinook salmon are now marked.

[4] A reintroduction program for spring Chinook salmon in the Hood subbasin is under way using out-of-ESU broodstock. Some natural production is occurring there. At this time, the origin of that natural production is unknown. For additional discussion of this reintroduction program, see Section 7.4.3.6.

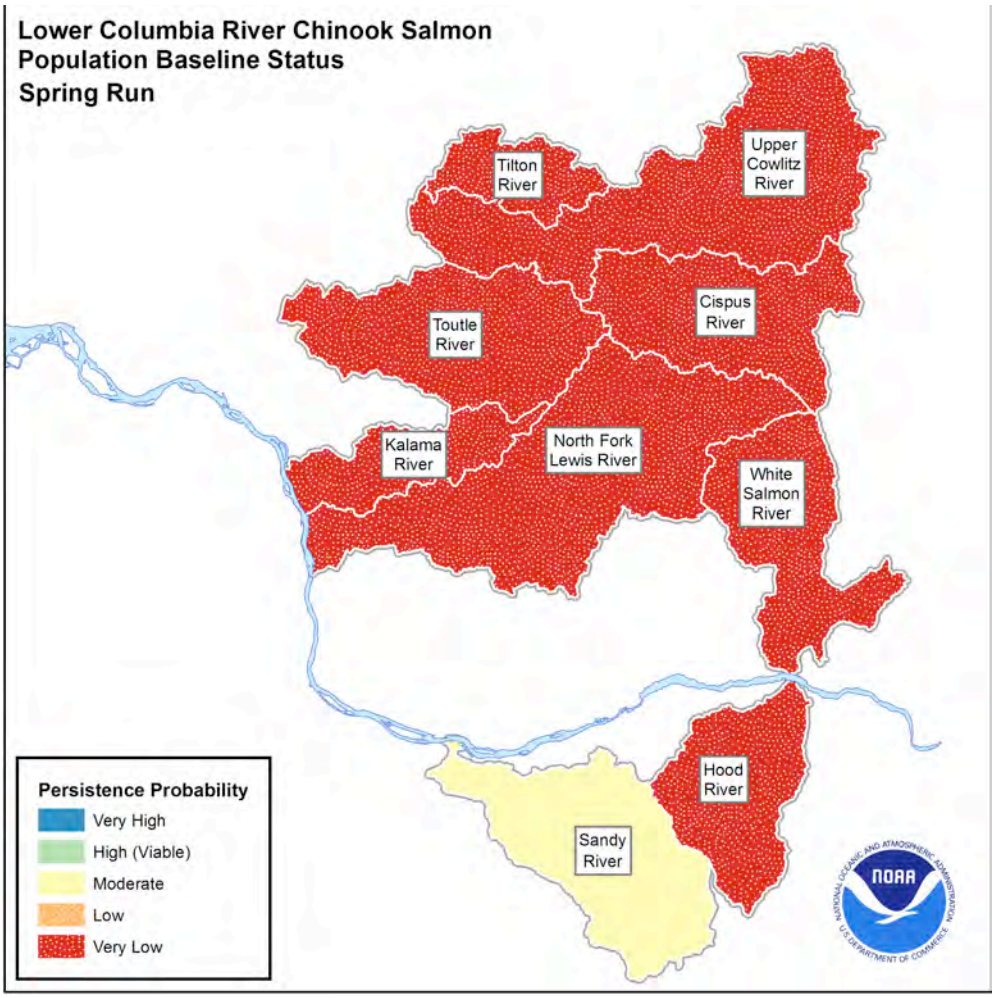


**Figure 7-3.** *Baseline Status of Lower Columbia River Spring Chinook Salmon Populations*

### 7.2.2 Baseline Status of LCR Tule Fall Chinook Salmon

Population status assessments conducted by Oregon and Washington management unit planners and based on the WLC TRT's recommended methods and criteria indicate that all 21 Lower Columbia River tule fall Chinook salmon populations have a baseline persistence probability of low or very low (see Figure 7-4) (LCFRB 2010a, ODFW 2010).

Spawner abundance and productivity estimates for these populations are generally based on expanded index-reach spawner counts and associated carcass sampling. In the past, data series used to estimate the hatchery proportion for most tule populations have been based on limited recoveries and, as a result, have had high uncertainty. Both the Oregon and Washington management unit plans identify obtaining improved estimates of annual abundance and wild/hatchery proportions of spawners as a short-term high-priority. In recent years, marking rates of tule Chinook salmon released from Lower Columbia River hatchery programs have significantly increased, facilitating estimates of hatchery-origin fish on natural spawning grounds. In addition, managers have reviewed carcass sampling efforts and expanded them in selected areas. Expansion methodologies

used to estimate total spawner abundance based on sub-area counts are also being reviewed and evaluated against mark-recapture methods. The Oregon and Washington management unit plans will incorporate improved estimates of spawner abundance and productivity into periodic updates of population persistence probability.

Declines in persistence probability among tule fall Chinook salmon are related primarily to losses in abundance, productivity, and diversity. With the exception of the Upper Cowlitz population, whose access to historical habitat is blocked by tributary dams,[5] Lower Columbia River tule fall Chinook salmon populations generally can access most areas of historical spawning habitat. However, the abundance of most natural populations is very low. Abundance and genetic and life history diversity likely have been reduced through habitat degradation, historically high harvest rates, historical stock transfers, pervasive hatchery effects, and small population bottlenecks in the natural populations. In addition, hatchery-origin fish spawning naturally may have decreased population productivity. Hatchery-origin fish make up a large fraction of the spawners in most natural production areas. Exceptions are the Coweeman and East Fork Lewis subbasins, where hatchery influence has been relatively low. These two populations are considered genetic legacy populations (LCFRB 2010a, ODFW 2010). Coast stratum populations in particular have been subject to high levels of non-local hatchery broodstock, which raises questions about the extent to which tule Chinook salmon currently spawning there represent the genetic diversity and adaptation that was originally present. The probable lack of locally adapted populations may be a contributing factor to the apparent low productivity of these populations; however, we have no direct information on the level of local adaptation in these populations, and we do not know the geographic scale at which local adaptation occurred historically (an uncertainty that is not limited to this stratum or ESU).

To be consistent with the management unit plans and the methodologies recommended by the WLC TRT, this recovery plan uses status information from the Oregon and Washington management unit plans (ODFW 2010 and LCFRB 2010a) in describing baseline status for Lower Columbia River fall Chinook salmon populations. However, two additional analyses have been conducted in recent years to inform Biological Opinions related to harvest. Ford et al. (2007) describes the results of two quantitative population viability models used to evaluate the probability of persistence for three tule populations—the Coweeman, Grays/Chinook, and Lewis—under alternative assumptions about future harvest rates. NMFS' Northwest Fisheries Science Center (NWFSC 2010) used a life-cycle modeling approach to analyze the impact of various harvest rates on population risk, taking into consideration the effects of hatcheries, habitat conditions, and a subset of recovery actions; this assessment evaluated eight of the tule populations targeted for high persistence probability.

The various assessments show considerable agreement about the status of Lower Columbia tule populations; for example, all of the assessments suggest that the Coast stratum tule Chinook salmon populations have low or very low probabilities of persistence, and most of the assessments suggest that the Coweeman and Lewis tule populations have slightly higher persistence probabilities than other tule populations.

[5] Until recently, Condit Dam blocked the White Salmon population's access to historical habitat. Condit Dam was breached in October 2011 and completely removed in September 2012.

However, the assessments sometimes differ in their estimates of the status of individual populations, with Ford et al. (2007) and the Northwest Fisheries Science Center (2010) suggesting higher persistence probabilities for some populations than the management unit plans. It is likely that these differences are due in part to the different purposes, assumptions, baseline dates, data sets, and applications of data sets among the assessments.

The Northwest Fisheries Science Center (2010) modeling suggests that there may be important distinctions in viability within the populations categorized by ODFW (2010) and LCFRB (2010a) as having a low or very low probability of persistence—especially in the populations' ability to sustain harvest. Populations modeled by the NWFSC generally fell into three categories: (1) relatively large populations with relatively low projected quasi-extinction risks under current habitat conditions, reduced harvest rate scenarios, and a range of hatchery impact assumptions, (2) those with very high current or past hatchery and habitat impacts that modeling suggests could not be naturally self-sustaining without substantial improvements, even with no harvest, and (3) populations that are intermediate between these two and could possibly sustain themselves without hatchery input at low harvest rates under current conditions and under some modeled assumptions but not others.

In the Northwest Fisheries Science Center (2010) modeling, the Coweeman, Lewis, and Washougal populations fall into the first category, while the Elochoman/Skamokawa, Clatskanie, and Scappoose populations fall into the second category; however, LCFRB's (2010a) population viability analysis suggests that the Lewis and Elochoman/Skamokawa fit more appropriately in the intermediate category, and that the Lower Cowlitz and Grays/Chinook populations fall into the first and second categories, respectively.

These differences in results point to the need for better understanding of the factors driving the very low productivity of some populations, including the influence of hatchery-origin spawners on natural tule populations, the impact of harvest on different populations, and the ability of current and projected habitat conditions to support self-sustaining populations.

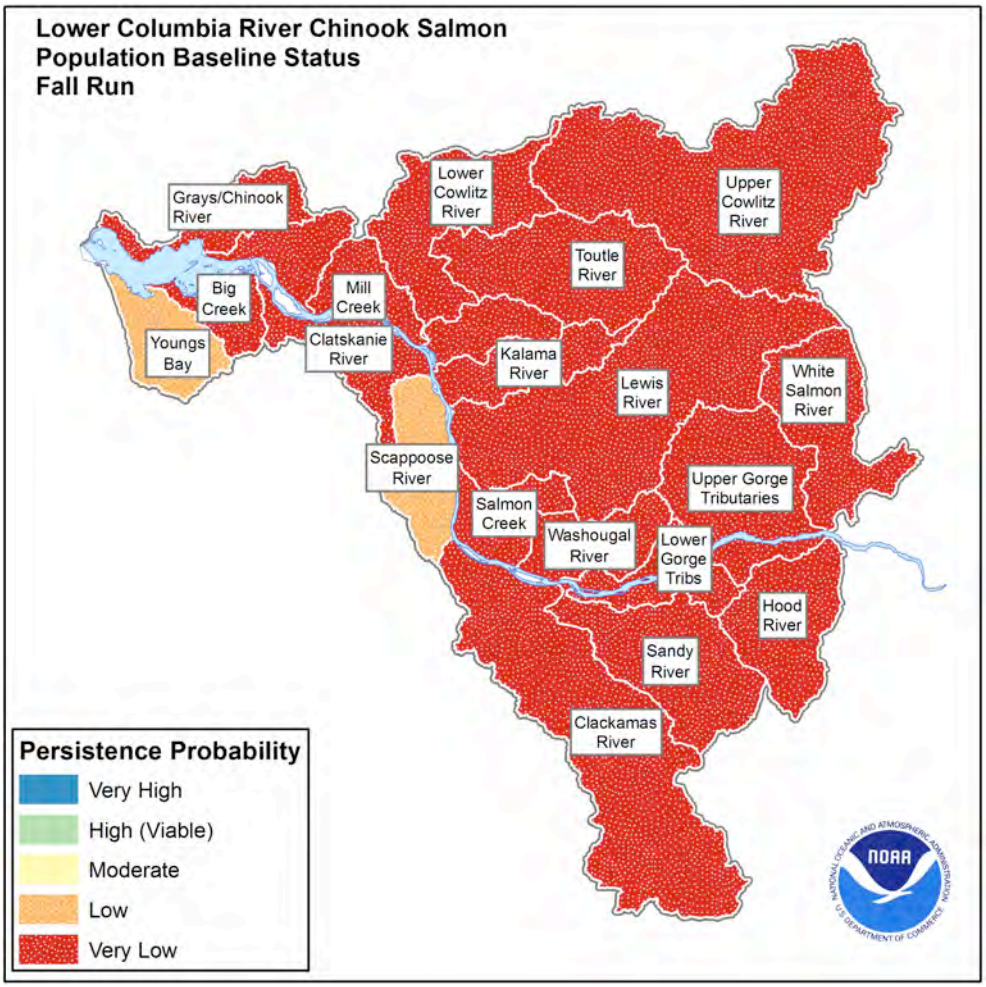


**Figure 7-4.** *Baseline Status of Lower Columbia River Fall (Tule) Chinook Salmon Populations, per Management Unit Plans*

### 7.2.3 Baseline Status of LCR Late-Fall (Bright) Chinook Salmon

The two late-fall Chinook salmon populations—North Fork Lewis and Sandy—are the only populations in this ESU whose baseline probability of persistence is estimated to be high (LCFRB 2010a, ODFW 2010). Both populations have remained largely uninfluenced by hatchery production and have not experienced the population bottlenecks seen in most tule fall Chinook salmon populations.

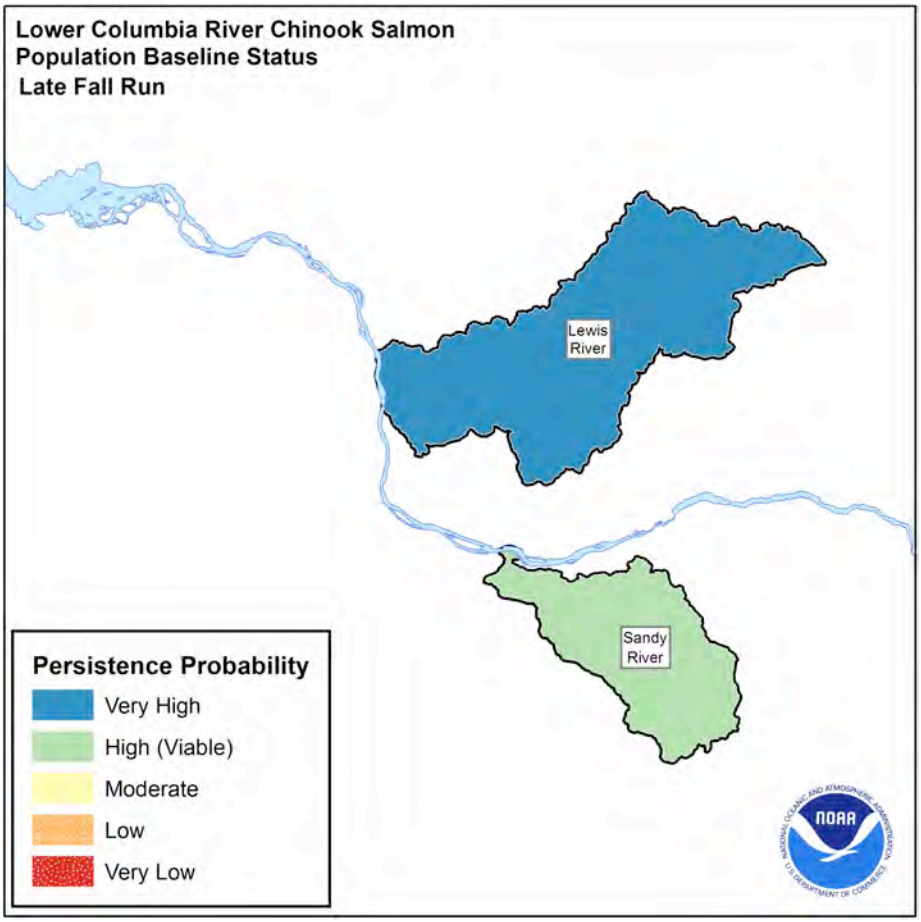


**Figure 7-5.** *Baseline Status of Columbia River Late-Fall Chinook Salmon Populations*

For additional discussion of Lower Columbia River Chinook salmon population status, see the management unit plans (LCFRB 2010a, pp. 6-7 through 6-13; ODFW 2010, pp. 54-55; and NMFS 2013, p. 4-1), Ford (2011), and, for Lower Columbia River tule fall Chinook salmon, Ford et al. (2007) and Northwest Fisheries Science Center (2010).

## 7.3 Target Status and Conservation Gaps for LCR Chinook Salmon Populations

Table 7-4 shows the baseline and target status for each Lower Columbia River Chinook salmon population, along with historical and target abundance. Local recovery planners coordinated with NMFS in making decisions about the target status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities. (Note: the target statuses in Table 7-4 are the same as the persistence probabilities in the recovery scenario presented in Table 3-1.) As described in Chapter 5, although Oregon and Washington recovery planners used somewhat different methodologies to estimate baseline status and target abundance and productivity, the management unit planners agree that the

methodologies led to similar conclusions regarding the generally low baseline status for most Lower Columbia River Chinook salmon populations.

Very large improvements are needed in the persistence probability of most spring and tule fall Chinook salmon populations if the ESU is to achieve recovery. For example, among the nine historical spring Chinook salmon populations, five are targeted for high or better persistence probability; four of these have baseline persistence probabilities of low or very low, or are extirpated or nearly so. Nine out of 21 tule fall Chinook salmon populations are targeted for high or better probability of persistence; all of these have a baseline persistence probability of very low or low. Some level of effort will be needed for every population to arrest or reverse long-term declining trends; this is true for stabilizing populations, which are expected to remain at their baseline persistence probability of low or very low, as well as for the two late-fall Chinook salmon populations, which need minimal improvement only. For most populations, meeting recovery objectives will require improvements in all VSP parameters: abundance, productivity, diversity, and spatial structure.

To achieve the recovery scenario for Cascade spring Chinook salmon, populations with high or better persistence probabilities must be reestablished in historical habitat blocked by tributary hydropower dams in the Upper Cowlitz, Cispus, and North Fork Lewis subbasins (all three of these populations were historically among the most productive, and the Upper Cowlitz is also a genetic legacy population), and in the Sandy subbasin (a core and genetic legacy population). In this stratum, only the Tilton population is expected to remain at its baseline persistence probability of very low, in part because of lower quality habitat. The Toutle spring Chinook salmon population is targeted to move from very low to medium persistence probability; this target status reflects uncertainties about how much spring Chinook salmon production the Toutle subbasin supported historically and concerns about the extent to which legacy effects of the Mount St. Helens eruption limit habitat productivity. The Kalama population is targeted to achieve low persistence probability, because habitat there was probably not as productive historically for spring Chinook salmon and because of the intent to maintain a fishery enhancement hatchery program there.

Achieving target status in the Gorge spring Chinook stratum will depend on reestablishing populations in the White Salmon and Hood River systems, where the historical populations are considered extirpated. Removal of Condit Dam in the White Salmon subbasin enhances prospects for recovery there, although questions remain about historical production and the potential to reestablish a population. (The dam was breached in October 2011 and completely removed in September 2012.) These questions led to a target of low-plus persistence probability for White Salmon spring Chinook salmon. The Oregon management unit plan is more optimistic that a viable spring Chinook salmon population can be reestablished in the Hood subbasin.[6]

Among the seven fall Chinook salmon populations in the Coast stratum, four are targeted for high persistence probability, including the Elochoman/Skamokawa, which is one of two core populations in the stratum. Big Creek, which is the other core

[6] Current reintroduction efforts in the Hood subbasin are using an out-of-ESU hatchery stock. See additional discussion of this issue below, in Section 7.4.3.6.

population, and the Youngs Bay population are targeted for low probability of persistence (up from very low for Youngs Bay). This decision reflects a strategic choice to provide harvest opportunity through terminal fisheries targeting hatchery fish in the Youngs Bay and Big Creek areas; consequently, the proportion of hatchery-origin spawners (pHOS) in these populations is expected to remain high. The Grays/Chinook population is targeted to move from very low to medium-plus persistence probability; this target status reflects concerns about potential habitat productivity and the ability to control stray hatchery fish, particularly from the Youngs Bay terminal fishery program.

In the Cascade fall Chinook stratum, four of ten populations are targeted for high-plus persistence probability, including the Toutle and Clackamas, which historically were among the most productive, and the Coweeman and Lewis, which are genetic legacy populations. Two populations are expected to remain at their very low baseline persistence probability: Salmon Creek, which is in a highly urbanized subbasin with limited habitat recovery potential, and the Upper Cowlitz, where reintroduction of spring Chinook salmon is the focus of recovery efforts (although fall Chinook are being passed into the Upper Cowlitz subbasin, as of 2010, in an effort to enhance that population).

In the Gorge fall Chinook stratum, only one of four populations—the Hood—is targeted for high persistence probability, with the other three populations targeted for medium persistence probability. In addition, the Oregon management unit plan notes that the feasibility of achieving the target status for the Hood population is low. Constraints to recovery for fall Chinook salmon in the Gorge include the small amount of historical and current habitat (and thus the limited options for restoration); anthropogenic impacts that are unlikely to change in the near future (e.g., inundation by Bonneville Reservoir and roads that restrict access to habitat); high uncertainty in the data and analyses for small populations[7]; and potentially inaccurate designation of population structure for this stratum. The Oregon management unit plan states that most of these issues are related to the population designation and suggests reevaluating the Gorge stratum population structure for all species (ODFW 2010).

The two populations of late-fall Chinook salmon are viable at their baseline levels, but the recovery scenario calls for the persistence probability of the Sandy population to be raised from high to very high.

If the scenario in Table 7-4 were achieved, it would exceed the WLC TRT's stratum-level viability criteria in the Coast and Cascade fall strata, the Cascade spring stratum, and the Cascade late-fall stratum (see Table 7-11).[8] However, the scenario for Gorge spring and Gorge fall Chinook salmon does not meet WLC TRT criteria because, within each

[7] In the method used by the WLC TRT and management unit planners to establish abundance goals, target abundance is based to some extent on the gap between current and historical abundance. If the historical abundance of Gorge stratum Chinook salmon populations has been significantly overestimated, then the abundance needed to achieve target status may also be overestimated (ODFW 2010).

[8] For example, in the Cascade fall stratum, four populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average viability score for all populations in the stratum would be 2.35. As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher.

stratum, the scenario targets only one population (the Hood) for high persistence probability. Exceeding the WLC TRT criteria, particularly in the Cascade fall and Cascade spring Chinook strata, was intentional on the part of local recovery planners to compensate for uncertainties about meeting the WLC TRT's criteria in the Gorge fall and spring strata. In addition, multiple spring Chinook salmon populations are prioritized for aggressive recovery efforts to balance risks associated with the uncertainty of success in reintroducing spring Chinook salmon populations above tributary dams in the Cowlitz and Lewis systems. (Delisting criteria for the Lower Columbia River Chinook salmon ESU are described in Section 3.2 and below in Section 7.7.)

Figures 7-6 and 7-7 display the population-level conservation gaps for tule fall Chinook, late-fall Chinook, and spring Chinook graphically. The conservation gap reflects the magnitude of improvement needed to move a population from its baseline status to the target status. For additional discussion of target status and conservation gaps for Lower Columbia River Chinook salmon populations, see the management unit plans (LCFRB 2010a, pp. 6-13 to 6-15 and ODFW 2010, pp. 148-150).

Given the structure of the Lower Columbia River Chinook salmon ESU, with its three major adult run components and both ocean- and stream-type juvenile life histories represented, the remainder of the Chinook salmon recovery analysis is broken down by run component: spring, fall, and late-fall. Limiting factor summaries, threat impacts, and recovery strategies at the run component level are nested appropriately within these three larger sections.

**Table 7-4**

*Baseline and Target Persistence Probability and Abundance of LCR Chinook Salmon Populations*

| | | | Baseline Persistence Probability[9] | | | | | Abundance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stratum** | **Population** | **Contribution** | **A&P** | **S** | **D** | **Net** | **Target Persistence Probability** | **Historical** | **Baseline[10]** | **Target** |
| Cascade | Upper Cowlitz (WA)[C, G] | Primary | VL | L | M | VL | H+ | 22,000 | 300 | 1,800 |
| spring | Cispus (WA)[C] | Primary | VL | L | M | VL | H+ | 7,800 | 150 | 1,800 |
| | Tilton (WA) | Stabilizing | VL | VL | VL | VL | VL | 5,400 | 100 | 100 |
| | Toutle (WA) | Contributing | VL | H | L | VL | M | 3,100 | 100 | 1,100 |
| | Kalama (WA) | Contributing | VL | H | L | VL | L | 4,900 | 100 | 300 |
| | NF Lewis (WA)[C] | Primary | VL | L | M | VL | H | 15,700 | 300 | 1,500 |
| | Sandy (OR)[C, G] | Primary | M | M | M | M | H | 26,899 | 714 | 1,230 |
| Gorge | White Salmon (WA)[C] | Contributing | VL | VL | VL | VL | L+ | -- [11] | < 50 | 500 |
| spring | Hood (OR) | Primary | VL | VH | VL | VL | VH | 15,041 | 327 | 1,493 |
| Coast | Youngs Bay (OR) | Stabilizing | L | VH | L | L | L | 15,115 | 379 | 505 |
| fall | Grays/Chinook (WA) | Contributing | VL | H | VL | VL | M+ | 800 | < 50 | 1,000 |
| | Big Creek (OR)[C] | Contributing | VL | H | L | VL | L | 8,785 | 216 | 577 |
| | Elochoman/Skamokawa (WA)[C] | Primary | VL | H | L | VL | H | 3,000 | < 50 | 1,500 |
| | Clatskanie (OR) | Primary | VL | VH | L | VL | H | 14,354 | 6 | 1,277 |
| | Mill/Abernathy/Germany (WA) | Primary | VL | H | L | VL | H | 2,500 | 50 | 900 |
| | Scappoose (OR) | Primary | L | H | L | L | H | 12,515 | 356 | 1,222 |
| Cascade | Lower Cowlitz (WA)[C] | Contributing | VL | H | M | VL | M+ | 24,000 | 500 | 3,000 |
| fall | Upper Cowlitz (WA) | Stabilizing | VL | VL | M | VL | VL | 28,000 | 0 | -- |

[9] A&P = Abundance and productivity, S = spatial structure, and D = genetic and life history diversity. Net = overall persistence probability of the population. VL = very low, L = low, M = moderate, H = high, VH = very high.

[10] Baseline abundance was estimated as described in Section 5.1 and does not equal observed natural-origin spawner counts. The baseline is a modeled abundance that represents 100-year forward projections under conditions representative of a recent baseline period using a population viability analysis that is functionally equivalent to the risk analyses in McElhany et al. (2007). Projections generally assume conditions similar to those from 1974 to 2004. Oregon numbers reflect fishery reductions between the 1990s and about 2004, while Washington numbers reflect fishery impacts prevalent in the period immediately prior to listing in 1999.

[11] "—" indicates that no data are available from which to make a quantitative assessment.

**Table 7-4**

*Baseline and Target Persistence Probability and Abundance of LCR Chinook Salmon Populations*

| | | | Baseline Persistence Probability[9] | | | | | Abundance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stratum** | **Population** | **Contribution** | **A&P** | **S** | **D** | **Net** | **Target Persistence Probability** | **Historical** | **Baseline[10]** | **Target** |
| | Toutle (WA)[C] | Primary | VL | H | M | VL | H+ | 11,000 | < 50 | 4,000 |
| | Coweeman (WA)[G] | Primary | L | H | H | L | H+ | 3,500 | 100 | 900 |
| | Kalama (WA) | Contributing | VL | H | M | VL | M | 2,700 | < 50 | 500 |
| | Lewis (WA)[G] | Primary | VL | H | H | VL | H+ | 2,600 | < 50 | 1,500 |
| | Salmon Creek (WA) | Stabilizing | VL | H | M | VL | VL | -- | < 50 | -- |
| | Clackamas (OR)[C] | Contributing | VL | VH | L | VL | M | 22,554 | 558 | 1,551 |
| | Sandy (OR) | Contributing | VL | M | L | VL | M | 6,237 | 144 | 1,031 |
| | Washougal (WA) | Primary | VL | H | M | VL | H+ | 2,600 | < 50 | 1,200 |
| Gorge | Lower Gorge (WA & OR) | Contributing | VL | M | L | VL | M | -- | < 50 | 1,200 |
| fall | Upper Gorge (WA & OR)[C] | Contributing | VL | M | L | VL | M | -- | < 50 | 1,200 |
| | White Salmon (WA)[C] | Contributing | VL | L | L | VL | M | -- | < 50 | 500 |
| | Hood (OR) | Primary | VL | VH | L | VL | H* | 1,391 | 33 | 1,245 |
| Cascade | NF Lewis (WA)[C, G] | Primary | VH | H | H | VH | VH | 23,000 | 7,300 | 7,300 |
| late fall | Sandy (OR)[C, G] | Primary | VH | M | M | H | VH | 10,000 | 1,794 | 3,561 |

C = Core populations, meaning those that historically were the most productive.

G = Genetic legacy populations, which best represent historical genetic diversity.

*Oregon's analysis indicates a low probability of meeting the delisting objective of high persistence probability for this population.

Source: LCFRB (2010a) and ODFW (2010).

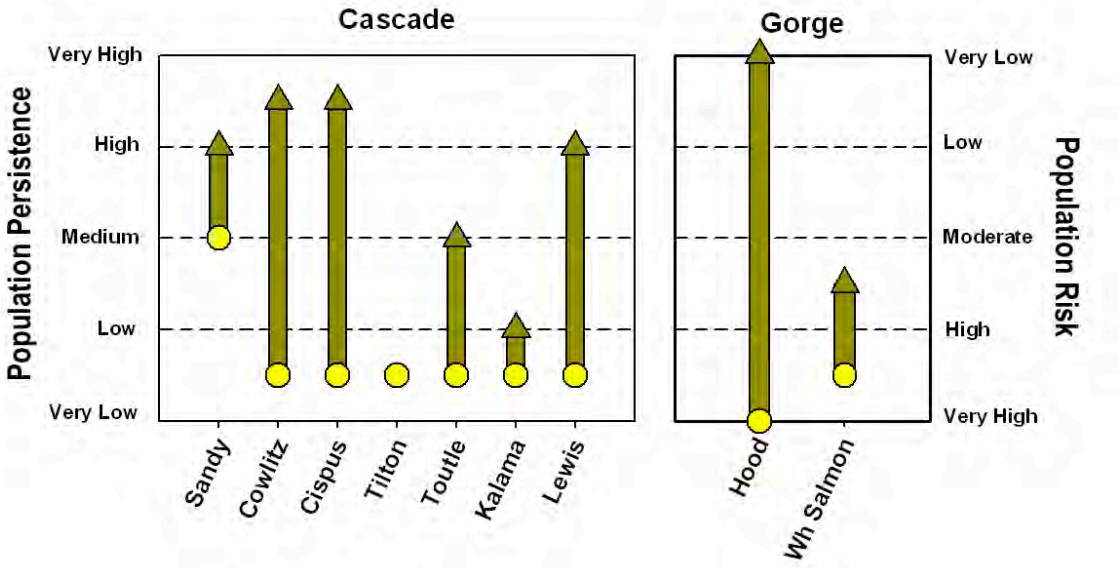


**Figure 7-6.** *Conservation Gaps for LCR Spring Chinook Salmon Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

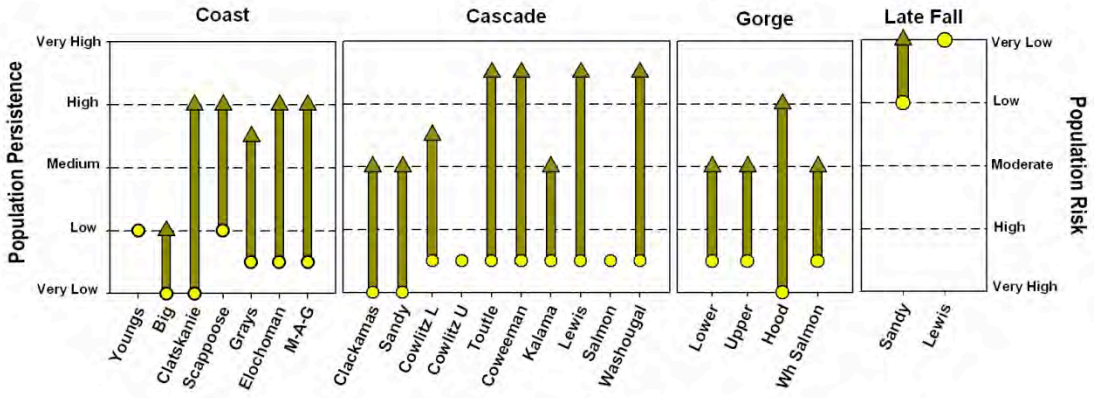


**Figure 7-7.** *Conservation Gaps for LCR Fall and Late-Fall Chinook Salmon Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

# 7.4 Spring Chinook Salmon Analysis: Limiting Factors, Threat Reductions, and Recovery Strategies

## 7.4.1 Spring Chinook Salmon Limiting Factors

Lower Columbia River spring Chinook salmon have been—and continue to be—affected by a legacy of habitat degradation, hydropower impacts, harvest, and hatchery production that, together, have reduced the persistence probability of all Lower Columbia River spring Chinook salmon populations. One of the largest factors limiting this component of the Lower Columbia River Chinook salmon ESU has been the existence of tributary dams that block access to core headwater spawning areas in upper subbasins.[12] Spatial structure, productive potential, and survival are further constrained by widespread degradation of tributary habitat in downstream areas. In addition, the high historical harvest rates and the effects of hatchery fish on natural populations have undermined the genetic and life history diversity of spring Chinook salmon populations and contributed to significant losses in production and abundance.

Table 7-5 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River spring Chinook salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead species (Hamm 2012; see Section 5.4). In addition, in Table 7-5, NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3).One difference relevant to the crosswalk is that although the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[13] the Washington management unit plan categorized limiting factors in this way only for habitat-related

[12] Steel and Sheer (2003) analyzed the number of stream kilometers of potential habitat historically and currently available to salmon populations in the lower Columbia River. For several spring Chinook salmon populations, historical habitat is almost completely blocked (100 percent in the Cispus and Tilton subbasins, 99 percent in the Upper Cowlitz, 76 percent in the Lewis, and—at the time of the analysis—100 percent in the White Salmon subbasin. Condit Dam, on the White Salmon River, was breached in October 2011 and completely removed in September 2012, thus eliminating the major blockage in that subbasin.). In the Toutle and Kalama subbasins much lower but still significant proportions of habitat are blocked (31 percent blocked in the Toutle and 23 percent in the Sandy). In the Kalama subbasin only 6 percent is blocked, and in the Hood, 1 percent.

[13] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

limiting factors, and the White Salmon plan and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). For populations that historically spawned in the White Salmon subbasin, NMFS staff inferred primary and secondary designations based on discussion in the Washington and White Salmon management unit plans (LCFRB 2010a, NMFS 2013). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting Lower Columbia River spring Chinook salmon, including magnitude, spatial scale, and relative impact (see LCFRB 2010a, Chapter 3 and various sections of Volume II; ODFW 2010, pp. 116-128; and NMFS 2013, Chapter 5). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Sections 7.4.2, 7.5., and 7.6.2 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

**Table 7-5**

*Baseline Limiting Factors and Threats Affecting LCR Spring Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Spring | Gorge Spring |
|---|---|---|---|---|
| **Tributary Habitat Limiting Factors** | | | | |
| Riparian Condition | Past and/or current land use practices | All | Primary for juveniles in all populations | Secondary for juveniles in all populations |

**Table 7-5**

*Baseline Limiting Factors and Threats Affecting LCR Spring Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Spring | Gorge Spring |
|---|---|---|---|---|
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | Secondary for juveniles in all populations |
| Peripheral and Transitional Habitats: Side Channel and Wetland Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | Secondary for juveniles in all populations |
| Peripheral and Transitional Habitats: Floodplain Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | Secondary for juveniles in all populations |
| Sediment Conditions | Past and/or current land use practices/ transportation corridor | All | Secondary for Sandy juveniles, primary for juveniles in all other populations | Secondary for juveniles in all populations |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dams | A,P,D | Primary for Tilton and Toutle juveniles, secondary for Kalama and North Fork Lewis juveniles | |
| Water Quantity (Flow) | Dams, land use, irrigation, municipal, and hatchery withdrawals | All | Secondary for juveniles in all populations | |
| **Estuary Habitat Limiting Factors**[14] | | | | |
| Toxic Contaminants | Agricultural chemicals, urban and industrial practices | A,P,D | Secondary for juveniles in all populations | |
| Food[15] (Shift from macrodetrital- to microdetrital-based food web) | Dam reservoirs | All | Secondary for juveniles in all populations | |

[14] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 7.4.1.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River spring Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[15] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

**Table 7-5**

*Baseline Limiting Factors and Threats Affecting LCR Spring Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Spring | Gorge Spring |
|---|---|---|---|---|
| Peripheral and Transitional Habitats: Estuary Condition | Past and/or current land use practices/transportation corridor, mainstem dams | All | Secondary for juveniles in all populations | |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | |
| Sediment Conditions | Past and/or current land use practices/transportation corridor, dams | All | Primary for juveniles in all populations | |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dam reservoirs | A,P,D | Secondary for juveniles in all populations | |
| Water Quantity (Flow) | Columbia River mainstem dams | All | Primary for juveniles in all populations | |
| **Hydropower Limiting Factors** | | | | |
| Habitat Quantity (Access) | Bonneville Dam | All | | Secondary for White Salmon and Hood |
| Habitat Quantity (Inundation) | Bonneville Dam | All | | Secondary for Hood juveniles[16] |
| Habitat Quantity (Access) | Tributary dams | All | Primary for Upper Cowlitz, Cispus, Tilton, and North Fork Lewis adults and juveniles, secondary for Sandy adults and juveniles | Primary for White Salmon adults and juveniles, secondary for Hood adults and juveniles |
| **Harvest Limiting Factors** | | | | |
| Direct Mortality | Fisheries | A,D | Primary for Upper Cowlitz, Cispus, Tilton, Toutle, Kalama, and North Fork Lewis adults, secondary for Sandy adults | Primary for Hood adults, secondary for White Salmon adults |

[16] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to spring Chinook salmon as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

**Table 7-5**

*Baseline Limiting Factors and Threats Affecting LCR Spring Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Spring | Gorge Spring |
|---|---|---|---|---|
| **Hatchery Limiting Factors** | | | | |
| Food[17] | Smolts from all Columbia Basin hatcheries competing for food and space in the estuary | All | Secondary for all populations | |
| Population Diversity | Stray hatchery fish interbreeding with wild fish | A,P,D | Primary for adults in all populations | Primary for adults in all populations |
| **Predation Limiting Factors** | | | | |
| Direct Mortality | Land use | A,P,D | Secondary for juveniles in all populations | |
| Direct Mortality | Dams | A,P,D | | Secondary for adults (marine mammals) and juveniles (non-salmonid fish) in all populations |

### *7.4.1.1 Tributary Habitat Limiting Factors*

Because spring Chinook salmon are stream-type salmon that typically rear in tributary reaches for a full year, they depend heavily on tributary habitat conditions for their survival (LCFRB 2010a). Loss and degradation of tributary habitat is one of the main limiting factors for Lower Columbia River spring Chinook salmon, along with blocked access to historical spawning habitat as a result of tributary hydropower dams (see Table 7-5).

Impaired side channel and wetland conditions and degraded floodplain habitat have significant negative impacts on juvenile spring Chinook salmon throughout the ESU and are identified as primary limiting factors for all Cascade spring populations and secondary factors for all Gorge spring populations. Extensive channelization, diking, wetland conversion, stream clearing, and, in some subbasins, gravel extraction have barred spring Chinook salmon from historically productive habitats and simplified much of the remaining tributary habitats, weakening watershed processes that are essential to the maintenance of healthy ecosystems. Degraded riparian conditions and channel structure and form issues also are primary limiting factors for all Cascade spring populations and secondary factors for all Gorge spring populations within the

[17] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS 2011a and LCFRB (2010) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

ESU. Lack of large woody debris and appropriately sized gravel in the remaining accessible tributary habitat has significantly reduced the amount of suitable spawning and rearing habitat for spring Chinook salmon.

Sediment conditions are identified as a primary limiting factor for all Washington populations with the exception of the White Salmon, but are considered to be secondary for the Oregon portion of the ESU.[18] The high density of forest and rural roads in the Lower Columbia subdomain, combined with past, and in some cases current, logging and other forest management practices and other land use patterns on unstable slopes adjacent to riparian habitat, contributes to an abundance of fine sediment in tributary streams.[19] The resulting excess fine sediment covers spawning gravel, limiting egg development and incubation, and increases turbidity. In addition, water quality—specifically elevated water temperature brought about through land use, lack of functioning riparian habitat, and reservoir operations—is a primary limiting factor for the Tilton and Toutle populations and a secondary limiting factor for the Kalama and North Fork Lewis populations. The influence of water storage and release operations, land use, and water withdrawals for irrigation, municipal use, and hatchery operations has led to altered hydrology and flow timing being identified as secondary factors for all spring Chinook salmon populations.

In the Cascade stratum, tributary habitat limiting factors are largely the same as those described above for all spring Chinook salmon populations. Land uses that have led to the conditions limiting habitat productivity in this stratum include forest management and timber harvest, agriculture, rural residential and urban development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development.

A unique issue in the Cascade stratum is legacy effects in the Toutle subbasin of the 1980 Mount St. Helen's eruption. The North Fork Toutle in particular was heavily affected by sedimentation from the eruption. A sediment retention structure (SRS) was constructed on the North Fork Toutle in an attempt to prevent continued severe sedimentation of stream channels and associated flood conveyance, transportation, and habitat degradation problems. The SRS currently blocks access to as many as 50 miles of habitat for anadromous fish. Although fish are transported around the structure via a trap and haul system, the SRS remains a source of chronic fine sediment to the lower river; this reduces habitat quality and has interfered with fish collection at the base of the SRS.

In addition, spawning of Sandy spring Chinook salmon is negatively affected by impaired gravel recruitment related to the City of Portland's Bull Run water system dams.

In the Gorge spring Chinook stratum, habitat limiting factors are generally the same as those described for all spring Chinook salmon populations, although tributary habitat

[18] This distinction is likely an artifact of differences in limiting factor assessment processes between the two states and not an actual physical difference in sediment conditions in tributary streams or their effects on Chinook populations.

[19] By itself, road density is not necessarily a good measure of delivery of fine sediment to streams.

limiting factors are identified as secondary. Riparian, side-channel, wetland, and floodplain habitat conditions have been compromised by land uses and inundation by the reservoirs behind Bonneville and Condit dams.[20] Land uses that have contributed to habitat limiting factors include forest management and timber harvest in the upper mainstem and headwater reaches of the Hood and White Salmon, and transportation and rural residential land uses, with some urban development, in lower mainstem and tributary reaches. Water quantity issues related to altered hydrology and flow timing—specifically caused by irrigation withdrawals or diversions or low-head hydro diversions—have been identified as secondary limiting factors.

Habitat within the White Salmon subbasin was altered by the breaching of Condit Dam (in October 2011, with full removal in September 2012). Alterations include near-term negative effects from sediment release and scouring. Scientists and managers expect long-term positive effects as the result of restoration of natural flow regimes and sediment transport, but monitoring is needed to evaluate habitat and fish response to dam removal, and additional assessment of habitat limiting factors will be needed to refine understanding of limiting factors.

#### *7.4.1.2 Estuary Habitat Limiting Factors[21]*

As stream-type fish, spring Chinook salmon spend less time in the Columbia River estuary and plume than do ocean-type salmon such as fall Chinook, yet estuary habitat conditions nevertheless play an important role in the survival of spring Chinook salmon juveniles, particularly those displaying less dominant life history strategies. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, also are a primary limiting factor for juveniles from all populations. Again, simplification of

[20] Condit Dam, in the White Salmon subbasin, was breached in October 2011 and completely removed in September 2012.

[21] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 7-5 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River spring Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor.

Lack of access to peripheral and transitional habitats, such as side channels and wetlands, is a secondary limiting factor for juveniles from all populations, with access being impaired by land uses—including the transportation corridor—and by flow alterations caused by mainstem dams. Other secondary limiting factors in the estuary that affect all spring Chinook populations are exposure to toxic contaminants (from urban, industrial, and agricultural sources) and elevated late summer and fall water temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs.[22] Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations. [23] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

### *7.4.1.3 Hydropower Limiting Factors*

Tributary hydropower development is one of the main limiting factors for Lower Columbia River spring Chinook salmon (see Table 7-5). In addition, flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River spring Chinook salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 7.4.1.2).[24] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Although the management unit plans identified temperature impacts of the hydropower system as a secondary limiting factor for all juvenile spring Chinook salmon, migration of juvenile spring Chinook salmon occurs from March through July and peaks in May (Dawley et al. 1986, McCabe et al. 1986, Roegner et al. 2004, Bottom et al. 2008, cited in Figure 2.2 of Carter et al. 2009). Thus, it is unlikely that elevated mainstem temperatures are having a significant impact on juvenile spring Chinook salmon. For the Hood and White Salmon populations, which spawn above Bonneville Dam, passage issues at Bonneville and

[22] Although the management plans identified temperature impacts as a secondary limiting factor for juveniles of all populations, the timing of juvenile spring Chinook salmon migration raises questions about the significance of this limiting factor; see Section 7.4.1.3.

[23] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[24] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

inundation of historical spawning habitat by the Bonneville Reservoir are identified as secondary limiting factors.[25]

In the Cascade stratum, tributary hydropower is a primary limiting factor for the Upper Cowlitz, Cispus, Tilton, and North Fork Lewis populations, which historically were among the most productive populations but which have been extirpated or nearly so as a result of blocked passage. In addition, tributary dams have had adverse impacts on downstream habitat through reduced gravel recruitment and other effects. Tributary hydropower issues related to downstream passage of juveniles were identified as a secondary limiting factor for Sandy spring Chinook salmon, but the PGE Bull Run Hydroelectric Project (which consisted of Marmot and Little Sandy dams) was removed in 2007-2008, so this is no longer a factor. There are no tributary hydropower facilities in the Toutle or Kalama subbasins.[26]

In the Gorge stratum, the presence of Condit Dam was identified as a primary limiting factor for the White Salmon population because, until recently, the dam blocked upstream passage to virtually all historical spring Chinook salmon spawning habitat. (Condit Dam was breached in October 2011 and completely removed in September 2012, so this limiting factor has been addressed.) Passage issues related to adult passage at Powerdale Dam in the Hood subbasin were identified as a secondary limiting factor, but the dam was removed in 2010. In addition, passage issues at Bonneville Dam have impacts on the Hood and White Salmon populations.

#### *7.4.1.4 Harvest Limiting Factors*

Harvest-related mortality is identified as a primary limiting factor for all spring Chinook salmon populations within the ESU except the Sandy, for which harvest is identified as a secondary limiting factor (because ODFW considered it more resilient to the impacts of harvest [ODFW 2010]). About three-quarters of the harvest that affects spring Chinook salmon takes place in ocean fisheries from Oregon to Alaska. Some harvest also occurs in commercial and recreational fisheries in the mainstem Columbia River below Bonneville Dam, in tributary fisheries targeting hatchery fish, and in Zone 6 tribal fisheries for Lower Columbia River spring Chinook salmon spawning above Bonneville Dam (a tribal fishery also targets the Hood population in the tributary). From 1980 to 1993, harvest rates on spring Chinook salmon harvest averaged 51 percent, but during the period since listing (i.e., 1999 to 2006) they dropped to approximately 20 percent (ODFW 2010).

Although both the Washington and Oregon recovery plans discuss harvest as a limiting factor for Lower Columbia River spring Chinook salmon, they do not consider baseline harvest rates as significant a limiting factor as dam passage constraints, tributary habitat degradation, and hatchery effects.

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[25] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to spring Chinook salmon as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

[26] However, the North Toutle sediment retention structure currently blocks access to as many as 50 miles of habitat for anadromous fish.

#### *7.4.1.5 Hatchery-Related Limiting Factors*

It is estimated that hatchery fish make up anywhere from 34 to 90 percent of spring Chinook salmon spawners, depending on the population in question (ODFW 2010, Table 4-8 and LCFRB 2010a, Table 3-8). Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish are identified as a primary limiting factor for all populations except the White Salmon. Hatchery straying, combined with past stock transfers, has likely altered the genetics of spring Chinook salmon populations and may have reduced diversity within the ESU. Productivity also has likely declined as a result of the influence of hatchery-origin fish. Notably, however, high proportions of hatchery-origin spawners are sometimes intentional because hatchery fish are being used to reintroduce spring Chinook salmon where they have been extirpated or nearly so (e.g., in the Hood, Cowlitz, and Lewis subbasins). In identifying hatchery-related limiting factors, the management unit plans evaluated only negative impacts of hatchery fish on productivity of natural fish and not the positive demographic benefits that such reintroduction programs can provide in the short term.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

#### *7.4.1.6 Predation*

Direct mortality from predation is a secondary limiting factor for all spring Chinook salmon populations. Anthropogenic changes to the structure of habitat have increased predator abundance and effectiveness and led to increased predation by Caspian terns, double-crested cormorants and various other species of seabirds in the Columbia River estuary and plume. Gorge spring Chinook salmon also face secondary predation threats from non-salmonid fish (primarily pikeminnows above and below the dam but also walleye and smallmouth bass in the reservoir) and from marine mammals (primarily sea lions) at Bonneville Dam.

### 7.4.2 Spring Chinook Salmon Baseline Threat Impacts and Threat Reduction Targets

Table 7-6 shows the estimated impact on each Lower Columbia River spring Chinook salmon population resulting from potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat

category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. The table also shows the overall percentage improvement that is needed to achieve the target impacts and corresponding population status.[27] These cumulative values across all threat categories (both baseline and target) are multiplicative rather than additive. Both the Oregon and Washington management unit plans use cumulative survivals across threat categories to illustrate the overall level of improvement needed. Each plan assumes that there is a direct proportional relationship between the projected changes in cumulative survival and the required changes in natural-origin spawner abundance and productivity. For populations where the survival improvement needed is larger than 500 percent, Table 7-6 does not report the exact value, in part because the value is highly uncertain.[28]

As an example, the baseline status of the Upper Cowlitz spring Chinook salmon population, circa 1999, has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 99.8 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 0.2 percent of the historical potential with no human impact. Tributary habitat, hydropower, harvest, and hatchery impacts each accounted for reductions in population productivity of 50 percent or more, with corresponding reductions in abundance, spatial structure, and diversity. The Washington management unit plan identifies a recovery strategy involving significant reductions in the impact of several threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 90 percent to 45 percent (i.e., an approximately 100 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 99.8 percent at baseline to 86.1 percent at the target status. This change would translate into a more than 500 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for Washington populations reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for Oregon populations reflect conditions through 2004. Dam impacts for Washington populations reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for Oregon

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[27] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: $[(1\text{-}Cumulative_{Target})\text{-}(1\text{-}Cumulative_{Baseline})]/[1\text{-}Cumulative_{Baseline}] \times 100$. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

[28] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

populations, the estimates of impacts in the "Dams" column of Table 7-6 reflect direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for Washington populations were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); for Oregon populations, recovery planners used hatchery impact rates equivalent to one-half the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting concern about genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 7-6 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 7-6 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 7-6 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 7-6 reflect policy decisions and the methodologies and assumptions used by the different recovery planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of spring Chinook exposed to that particular category of threats, whether or not they are exposed to threats in the other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[29] As more and better

[29] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 7-6, almost every spring Chinook salmon population is greatly affected by the loss and degradation of tributary habitat, and five populations—the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and White Salmon—have experienced impacts from tributary dams that are comparable to or even greater than those associated with other factors that affect tributary habitat. Accordingly, for most populations, the greatest gains in viability are expected from tributary habitat and dam passage improvements (combined with hatchery reintroduction programs). Exceptions are the Tilton—a stabilizing population that is expected to remain at its baseline status—and the Sandy and Hood populations, for which reductions in hatchery impacts are targeted to provide the greatest benefit.

Baseline hatchery and harvest impacts also are significant for most spring Chinook salmon populations. Although recent actions have substantially reduced harvest of spring Chinook salmon from baseline conditions, ancillary and precautionary actions are needed to ensure that harvest does not adversely affect conservation and recovery in the future. For all but the Tilton population, hatchery-related impacts are targeted to be reduced by half or more, with the largest reductions targeted in the Sandy and Hood populations.[30] Achieving recovery goals also will require improvements in predation management and estuary habitat impacts; however, net reductions in these threat categories are smaller than those for tributary habitat, hydropower, hatcheries, and harvest because the impacts of estuarine and predation threats are less.

Four of the nine spring Chinook salmon populations are targeted for significant reductions in every threat category, including hydropower (in the form of tributary dam removal or upstream and downstream passage improvements). These populations are the Upper Cowlitz, Cispus, North Fork Lewis, and White Salmon. Of these, only the White Salmon is not designated as primary.

More information on threat reduction scenarios, including methodologies used to determine baseline and target impacts, is available in the management unit plans (ODFW 2010, pp. 151-177 and LCFRB 2010a, pp. 4-30 through 4-33, and 6-49 through 6-52).

[30] See the discussion below, in Section 7.4.3.6, regarding use of out-of-ESU stock for reintroducing spring Chinook salmon in the Hood River.

**Table 7-6**

*Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Spring Chinook Salmon Populations*

| Population | Impacts at Baseline[31] | | | | | | | Impacts at Target | | | | | | | % Survival Improve-ment Needed[39] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[32] | Est[33] | Dams[34] | Harv[35] | Hat[36] | Pred[37] | Cumul-ative[38] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumul-ative | |
| **Cascade Spring** | | | | | | | | | | | | | | | |
| Upper Cowlitz (WA) | 0.90 | 0.15 | 0.90 | 0.50 | 0.50 | 0.22 | 0.9983 | 0.45 | 0.08 | 0.45 | 0.25 | 0.25 | 0.11 | 0.8607 | >500 |
| Cispus (WA) | 0.90 | 0.15 | 1.00 | 0.50 | 0.50 | 0.22 | 1.0000 | 0.45 | 0.08 | 0.50 | 0.25 | 0.25 | 0.11 | 0.8733 | >500[40] |

[31] Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

[32] Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

[33] Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

[34] Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

[35] Includes direct and indirect mortality.

[36] Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

[37] Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

[38] Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$. Minor differences from numbers in ODFW 2010 are due to rounding.

[39] Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target). For most populations this was calculated using the following equation: $[(1-\text{Cumulative}_{Target})-(1-\text{Cumulative}_{Baseline})]/[1-\text{Cumulative}_{Baseline}] \times 100$. These cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts. For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 7.4.2

[40] The Cispus population requires improvements in every threat category. However, given that hydropower impacts are 100 percent for this population, it will not benefit from improvements in other threat categories until some degree of passage is restored. Although passage improvements alone will not lead to recovery, how successful passage improvements are will greatly influence how much improvement is needed in the other threat categories. The Tilton population also has hydropower impacts of 100 percent but is a stabilizing population not targeted for improvements in any threat category. Because hydropower impacts are 100 percent for both these populations, the formula for percent survival improvement for these populations was modified to account for the 100 percent hydropower impacts (i.e., to avoid having to divide by zero).

**Table 7-6**

*Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Spring Chinook Salmon Populations*

| Population | Impacts at Baseline[31] | | | | | | | Impacts at Target | | | | | | | % Survival Improve-ment Needed[39] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[32] | Est[33] | Dams[34] | Harv[35] | Hat[36] | Pred[37] | Cumul-ative[38] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumul-ative | |
| Tilton (WA) | 0.80 | 0.15 | 1.00 | 0.50 | 0.50 | 0.22 | 1.0000 | 0.80 | 0.15 | 1.00 | 0.50 | 0.50 | 0.22 | 1.0000 | 0 |
| Toutle (WA) | 0.90 | 0.15 | 0.00 | 0.50 | 0.50 | 0.22 | 0.9834 | 0.45 | 0.08 | 0.00 | 0.25 | 0.25 | 0.11 | 0.7467 | >500 |
| Kalama (WA) | 0.90 | 0.15 | 0.00 | 0.50 | 0.50 | 0.22 | 0.9834 | 0.45 | 0.08 | 0.00 | 0.25 | 0.25 | 0.11 | 0.7467 | >500 |
| NF Lewis (WA) | 0.40 | 0.15 | 0.95 | 0.50 | 0.50 | 0.22 | 0.9950 | 0.20 | 0.08 | 0.48 | 0.25 | 0.25 | 0.11 | 0.8084 | >500 |
| Sandy (OR) | 0.94 | 0.10 | 0.08 | 0.25 | 0.27 | 0.12 | 0.9761 | 0.92 | 0.08 | 0.00 | 0.25 | 0.05 | 0.07 | 0.9512 | 100 |
| **Gorge Spring** | | | | | | | | | | | | | | | |
| White Salmon (WA)[41] | 0.70 | 0.14 | 0.96 | 0.50 | 0.50 | 0.27 | 0.9981 | 0.35 | 0.07 | 0.48 | 0.25 | 0.25 | 0.13 | 0.8462 | >500 |
| Hood (OR) | 0.89 | 0.10 | 0.35 | 0.25 | 0.45 | 0.16 | 0.9777 | 0.82 | 0.08 | 0.12 | 0.25 | 0.05 | 0.07 | 0.9034 | 330 |

[41] Baseline and target impacts for the Upper Gorge/White Salmon population are from LCFRB (2010a).

## 7.4.3 Spring Chinook Salmon Recovery Strategy

### *7.4.3.1 Strategy Summary*

The recovery strategy for spring Chinook salmon is aimed at restoring the Cascade spring stratum to a high probability of persistence and improving the persistence probability of the two Gorge spring populations. Although the strategy involves threat reductions in all categories, the most crucial elements are as follows:

1. Protect and improve the Sandy spring Chinook salmon population, which is the best-performing population and the only Lower Columbia River spring Chinook salmon population with appreciable natural production. This will be accomplished by protecting high-quality, well-functioning spawning and rearing habitat, reducing the proportion of hatchery-origin spawners (pHOS), managing predation, and restoring tributary and estuarine habitat.[42]

2. Reestablish naturally spawning populations above dams on the Cowlitz and North Fork Lewis rivers, in areas that historically were highly productive, by improving adult and juvenile dam passage and developing hatchery reintroduction programs using broodstock from within-subbasin hatchery programs. Reestablishing populations in mid- to upper-elevation habitats is key to recovering the spring component of the Lower Columbia River Chinook salmon ESU.

3. Protect favorable tributary habitat and restore degraded but potentially productive habitat, particularly in the upper subbasins where spring Chinook salmon hold, spawn, and rear. Tributary habitat improvements are crucial for all populations.

4. Reestablish spring Chinook salmon in the White Salmon and Hood subbasins.

Very large improvements will be needed in the persistence probability of most spring Chinook salmon populations if the Lower Columbia River Chinook salmon ESU is to recover. (See Table 7-4 for the target persistence probability for each spring Chinook salmon population and Figure 7-6 for the gaps between baseline and target status.) Improving the status of the two Gorge populations will be difficult because of the challenges of reestablishing an extirpated population in the White Salmon subbasin after the removal of Condit Dam and of developing a locally adapted population in the Hood subbasin based on hatchery reintroduction. To compensate for limited prospects in the Gorge stratum, a goal of high persistence probability has been established for more than the minimum number of populations in the Cascade spring Chinook stratum.

The recovery strategy for spring Chinook salmon is a long-term, "all-H" approach in which plan implementers begin work on all of the elements described above immediately and implement actions associated with each of the six threat categories

[42] Some reduction in impacts on the Sandy population already have been achieved through removal of Marmot Dam and the Little Sandy River diversion in 2008 and protection of associated instream water rights for fish.

simultaneously.[43] As part of a series of 3- to 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation). Recovery will require improvements in every threat category, even those improvements in Table 7-6 that are relatively small. Although restoring effective passage into historical natural production areas in the upper Cowlitz and Lewis systems will be key in meeting recovery objectives for spring Chinook salmon, the full potential of dam passage improvements will be limited without significant habitat restoration and protection. Site-specific restoration is needed in upper subbasins immediately, along with implementation of tributary habitat protection and watershed-based restoration actions; these measures will ensure adequate habitat quantity and function for viable populations over the long term. Harvest rates will be maintained at their current relatively low level until actions in other threat categories have taken effect; once populations have been reestablished above tributary dams and natural production has increased, harvest rates can be reevaluated.

Key critical uncertainties that need to be addressed to support implementation of near-term actions relate to passage efficiencies past tributary dams, juvenile production in upper subbasins, the pace at which reintroduced populations become functional and self-sustaining, and the amount of pinniped predation on spring Chinook salmon in the Columbia River estuary (see Section 7.4.3.8).

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013).

#### *7.4.3.2 Tributary Habitat Strategy*

Spring Chinook salmon will benefit from the regional tributary habitat strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning spring Chinook salmon and steelhead habitat through a combination of (1) site-specific management actions that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Actions of particular benefit to spring Chinook salmon focus on protecting and restoring floodplain connectivity and function, access to side channels and off-channel habitats, and habitat complexity and diversity, especially in mid- to high-elevation habitat. Improving riparian cover and recruitment of large wood to streams also will be a priority. Headwater areas are targeted for protection and restoration to maintain sources of cool, clean water and normative hydrologic conditions; this includes protecting intact forests, managing forest lands to protect watershed processes and habitat conditions (LCFRB 2010a), and restoring upland processes that will reduce inputs of fine sediment to the spawning

[43] Implementation of recovery actions to reduce threats in each category is already under way, although the scale of effort is less than that called for in this recovery plan.

gravel of spring Chinook salmon. The subsections below summarize additional, stratum-specific tributary habitat strategies for spring Chinook salmon.

**Cascade Spring Chinook Salmon Tributary Habitat Strategies**

In implementing the Lower Columbia River spring Chinook salmon tributary habitat strategy in the Cascade stratum, considerations include the following:

- Generally, habitat conditions are favorable in the upper portions of the Cowlitz, Cispus, and North Fork Lewis subbasins, where populations are targeted for high or high-plus persistence probability but where access has been blocked by dams. In these areas, protecting high-quality habitat and restoring upslope processes, valley floodplain function, and stream habitat diversity will be priorities. Large portions of these areas are in federal forest land, which highlights the importance of Northwest Forest Plan implementation to protect habitats in those areas.

- Particularly for the Washington populations, substantial restoration also will be needed in currently accessible areas. Because spring Chinook salmon use mid- to high-elevation valley habitats for spawning and rearing, restoration efforts will focus on such areas, both in historically highly productive watersheds as well as some where production potential is more limited. Actions will include those described above for spring Chinook salmon generally.

- Habitat conditions are generally favorable in the Sandy subbasin (this population is targeted for high persistence probability). Again, large portions of this subbasin are in federal forest land. Implementation of the City of Portland's Bull Run water supply habitat conservation plan will also play a key role in habitat restoration and protection in the Sandy subbasin. Under this plan, the city will implement habitat actions throughout the subbasin as mitigation for its water supply project on the Bull Run River.

- State or private forest land predominates in the upper portions of the Toutle, Kalama, and North Fork Lewis subbasins. These lands must be managed to protect and restore watershed processes.

Addressing passage barriers such as culverts will benefit Cascade spring Chinook salmon populations by restoring access to habitat in a number of locations, including the North Fork Lewis, Tilton, Cispus, and Upper Cowlitz subbasins. (In some cases, additional assessment is needed to inventory and prioritize these blockages.) For the Toutle population, addressing sedimentation and passage issues at the North Fork Toutle sediment retention structure will be key.

Assuming that the impacts of other threats are reduced to the levels shown in Table 7-6, the scale of habitat improvements needed for Cascade spring Chinook stratum populations is minimal in the case of the Sandy population and the Tilton population,

which, as a stabilizing population, is expected to remain at its baseline status.[44] For the Upper Cowlitz, Cispus, Toutle, Kalama, and North Fork Lewis populations, baseline impacts to tributary habitat productivity are targeted to be reduced by 50 percent to meet recovery targets.

**Gorge Spring Chinook Salmon Tributary Habitat Strategies**

In implementing the Lower Columbia River spring Chinook salmon tributary habitat strategy in the Gorge stratum, considerations include the following:

- Gorge populations occur in watersheds that are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.

The Oregon management unit plan identifies an approximately 8 percent reduction in tributary habitat impacts needed to achieve the target status for the Hood spring Chinook salmon population. Site-specific actions will focus on restoring or creating off-channel and side-channel habitat (alcoves, wetlands, floodplains, etc.), providing access to off-channel and side-channel habitat, and restoring riparian areas and instream habitat complexity, including recruitment of large wood to streams. Because water quantity issues associated with irrigation withdrawals are identified as a limiting factor for the Hood spring Chinook salmon population, the Oregon management unit plan identifies a number of actions to address flow issues (e.g., ensure that low-head hydropower projects do not adversely impact winter streamflows and work the Oregon Water Resources Department and others to keep water saved through publicly funded water conservation efforts instream for fish).

In the White Salmon subbasin, all historical spring Chinook salmon habitat is assumed to be located above Condit Dam. The breaching of Condit Dam in October 2011 (with full removal in September 2012) created near-term negative effects in the habitat below the dam and the habitat within the footprint of the former reservoir because of sediment release and scouring. Long-term effects are expected to be positive because of restored natural flow and sediment transport regimes. The White Salmon plan outlines four broad tributary habitat strategies: (1) gain information to identify and prioritize habitat actions, (2) when the dam is removed, restore mainstem habitat, (3) protect and conserve natural ecological processes, and (4) improve habitat in upriver reaches (NMFS 2013). In the near term, evaluating the effects on of the dam breaching and removal on habitat and performing additional assessment of habitat limiting factors are high priorities.

### *7.4.3.3 Estuary Habitat Strategy*

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Lower Columbia River spring Chinook salmon. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2). The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with

[44] Because of dam passage issues and relatively low habitat quality, the Tilton population is expected to remain at its baseline probability persistence of very low.

actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a).

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of spring Chinook salmon leaving the Columbia River estuary. Oregon and Washington management recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for spring Chinook salmon populations based on the estuary module and their own approaches to threat reductions (ODFW 2010, Tables 6-24 and 6-25; LCFRB 2010a, Table 6-2).

#### *7.4.3.4 Hydropower Strategy*

The hydropower recovery strategy for Lower Columbia River spring Chinook salmon is to address the impacts of tributary hydropower dams through implementation of FERC relicensing agreements and thereby reestablish viable spring Chinook salmon populations in the Upper Cowlitz, Cispus, and North Fork Lewis subbasins; achieve survival gains in the Sandy, White Salmon, and Hood populations; and maintain the Tilton population at its baseline persistence probability of very low. Accomplishing these objectives will involve the removal of FERC-licensed dams (completed in the Sandy, Hood, and White Salmon) and development of adult and juvenile passage systems and hatchery reintroduction programs in the Cowlitz (Upper Cowlitz, Cispus populations) and Lewis subbasins.[45]

The strategy also includes measures to improve passage survival at Bonneville Dam for the Hood and White Salmon populations and implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. NMFS estimates that survival of spring Chinook salmon passing Bonneville Dam was 95.1 percent for juveniles from 2002 to 2009 and 98.6 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expected that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement would improve juvenile spring Chinook salmon survival at Bonneville Dam by less than ½ percent, and that adult survival would be maintained at recent high levels (NMFS 2008a). Consequently, Oregon did not incorporate survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[46] The Washington management unit plan assumed that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement would aid adults and juveniles from all Lower Columbia River spring Chinook salmon populations originating above Bonneville Dam. However, preliminary information indicates that survival gains for yearling Chinook at Bonneville Dam are higher than expected and are above 96 percent (U.S. Army Corps of Engineers 2011b).

[45] Spring Chinook salmon will likely also be reintroduced into the Tilton subbasin eventually, but those efforts will be delayed to facilitate reintroduction into the Upper Cowlitz and Cispus subbasins.
[46] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

For more on actions to improve mainstem dam passage, see the regional hydropower strategy in Section 4.3.2.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for spring Chinook salmon.

**Cascade Spring Chinook Salmon Hydropower Strategy**

The Cascade-stratum hydropower strategy is crucial to successful recovery of the spring life history component of the Lower Columbia River Chinook salmon ESU. The strategy involves creating or improving passage at projects on the Cowlitz and Lewis rivers and using hatchery reintroduction programs to reestablish viable populations in the Upper Cowlitz, Cispus, and North Fork Lewis subbasins (the Tilton population, in the Cowlitz system, is not expected to improve above its baseline persistence probability of very low). These changes are being implemented under the terms of FERC relicensing agreements completed with Tacoma Power for the Cowlitz River Project (Settlement Agreement completed in 2000) and with PacifiCorp and the Cowlitz PUD for the Lewis River Hydroelectric Projects (Settlement Agreement in 2004). Although there are many challenges to reestablishing natural spawning above the dams, the upper portions of the Cowlitz, Cispus, and North Fork Lewis subbasins still have relatively intact and well-functioning habitat that support spring Chinook salmon spawning and rearing.

In the Cowlitz subbasin, the hatchery Barrier Dam prevents all volitional passage of anadromous fish above RM 49.5. Currently, spring Chinook salmon are collected, natural-origin fish are separated from hatchery broodstock, and natural-origin fish are transported upstream of Barrier, Mayfield, Mossyrock, and Cowlitz Falls dams and released into the Upper Cowlitz and Cispus rivers.[47] Spring Chinook salmon smolts are collected at Cowlitz Falls Dam, briefly held in stress-relief ponds, and released into the lower Cowlitz (LCFRB 2010a). Survival of juveniles through reservoirs and past dams is especially problematic in this system (LCFRB 2010a). Both upstream passage and downstream passage at these dams are expected to be improved as part of the 2002 FERC relicensing order. High collection rates of downstream migrants will be key to

[47] Spring Chinook salmon will likely also be reintroduced into the Tilton subbasin eventually, but those efforts will be delayed to facilitate reintroduction into the Upper Cowlitz and Cispus subbasins.

recovery of the populations above Cowlitz Falls. Tacoma Power will evaluate fish returns and survival through the reservoirs and assess passage options. Adult passage at Mayfield Dam will be by trap and haul unless certain settlement agreement criteria (fish sorting, productivity, etc.) are met. If met, then passage at Mayfield Dam is likely to be provided through construction of a ladder, whereas passage at the much larger Mossyrock Dam would likely be provided by either trap and haul or a tramway.

In the North Fork Lewis subbasin, three dams—Merwin, Yale, and Swift—block passage to the upper North Fork Lewis, starting with Merwin Dam at RM 20. As part of the 2004 FERC relicensing agreement with PacifiCorp and the Cowlitz Public Utility District, spring Chinook salmon will be reintroduced into habitat upstream of the three dams. Almost all remaining historical spring Chinook salmon spawning habitat for the North Fork Lewis population is located in the upper North Fork Lewis watershed, above Swift Reservoir (LCFRB 2010a). The keys to successful reintroduction will be adequate passage of adults to and juveniles from the upper watershed, hatchery supplementation, and habitat improvements. In addition, because hydroregulation on the Lewis River has altered the natural flow regime below Merwin Dam, further adjustments in flow regime may be needed to provide adequate flows for habitat formation, fish migration, water quality, floodplain connectivity, habitat capacity, and sediment transport.[48] However, floodplain and channel alterations in the lower river will limit the ability of changes in flow regime to restore lower floodplain function, so flow modifications will need to take place in concert with restoration of lower river floodplain function.

Downstream passage of juveniles through tributary hydropower projects was identified as a secondary limiting factor for the Sandy spring Chinook salmon population, but the PGE Bull Run Hydroelectric Project (consisting of Marmot and Little Sandy dams) was removed in 2007-2008, so this is no longer a limiting factor.

**Gorge Spring Chinook Salmon Hydropower Strategy**

Tributary hydropower impacts for the White Salmon and Hood populations largely have been addressed by the removal of Condit and Powerdale dams, respectively. Condit Dam, operated on the White Salmon River by PacifiCorp, was breached in October 2011 and, under the terms of a 1999 decommissioning agreement and a 2006 Biological Opinion, was completely removed in September 2012. Removal reopens access to 12.8 miles of historical spring Chinook salmon habitat (NMFS 2013). This represents virtually all the historical habitat for the White Salmon spring Chinook salmon population. Now that dam removal has been completed, natural escapement and production will be monitored for 4 to 5 years; if recolonization has not occurred adequately by that time, appropriate hatchery adults and/or juveniles may be released into the White Salmon River.

Powerdale Dam, on the Hood River, and also operated by PacifiCorp, was removed in 2010 under the terms of a settlement agreement reached in 2003. The dam acted as a partial barrier that delayed upstream migration of returning adults.[49] Removal of

[48] Changes in flow regime will need to consider the needs of all listed species in the Lewis Basin.
[49] Downstream migrants were not entrained or delayed at Powerdale Dam once hydropower operations were suspended in late 2006.

Powerdale will eliminate this hydropower-related mortality for the Hood spring Chinook salmon population.

Actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will also provide slight improvements in juvenile survival for the two Gorge spring Chinook salmon populations (see the regional hydropower strategy in Section 4.3.2).

#### *7.4.3.5 Harvest Strategy*

Harvest impacts on natural-origin spring Chinook salmon averaged about 51 percent per year around the time of listing and currently are around 20 percent (about half of which occurs in mixed-stock ocean fisheries). The Oregon management unit plan considers a baseline harvest rate of 25 percent to be consistent with recovery of natural-origin spring Chinook salmon and does not include reductions in harvest in its population threat reduction scenarios for spring Chinook salmon (ODFW 2010); however, the Oregon management unit plan does include ancillary and precautionary actions to ensure that harvest does not adversely affect conservation and recovery in the future.

The Washington management unit plan also estimated that fishery impacts of 25 percent were consistent with long-term objectives. For harvest in general, the Washington management unit plan recommends a phased harvest strategy involving lower near-term rates to reduce population risks until habitat has improved. Modeling in the plan shows a scenario in which spring Chinook salmon harvest rates would be managed for benchmarks of 15 to 25 percent for three consecutive 12-year evaluation periods (i.e., from 1999-2010, 2011-2022, and 2023-2034). The 15 to 25 percent benchmark reflects the possible need for (1) rates lower than 25 percent in some years to reduce the risk of critically low escapements in years of low ocean survival, and (2) fishery restrictions within selected subbasins to protect local populations (LCFRB 2010a). Then, the modeling shows that, assuming that habitat improvements have been achieved and hatchery reintroductions have been successful in establishing natural production, harvest impacts on natural-origin fish could then be higher, in the range of 20 to 30 percent (LCFRB 2010a). These modeling results are planning targets and not predictions of future harvest rates; managers will establish future harvest rates based on observed indicators in Lower Columbia River spring Chinook salmon populations.

Although near-term harvest impact reduction benchmarks have been met (in the case of the Washington management unit plan) or are not needed (in the case of the Oregon management unit plan), the plans do contain some actions related to spring Chinook salmon that are consistent with the regional harvest strategy (see Section 4.5.2). Most of these actions have either already been implemented or involve the continuation of ongoing efforts, including the following:

- Supporting mark-selective ocean fisheries when the Pacific Salmon Treaty is renegotiated in 2018 (ODFW 2010).
- Employing time and area restrictions to address specific annual or population concerns (LCFRB 2010a, ODFW 2010).

Over the long term, as reintroduction and passage improvement efforts begin to yield more natural production, it will be necessary to reevaluate harvest impacts and determine an appropriate harvest strategy.

**Cascade Spring Chinook Salmon Harvest Strategy**

The Lower Columbia River spring Chinook salmon harvest strategy described in Section 7.4.3.5 will benefit populations in this stratum.

**Gorge Spring Chinook Salmon Harvest Strategy**

The ESU-level harvest strategies described in Section 7.4.3.5 will benefit populations in this stratum. In addition, because Lower Columbia River spring Chinook salmon spawning above Bonneville Dam (i.e., the Hood population at present, but once they are reestablished, the White Salmon population as well) are intercepted in Zone 6 tribal fisheries, the Oregon management unit plan includes an action to discuss with tribes potential actions to reduce those impacts. (Potential actions include extending sanctuaries from the mouths of tributaries and/or modifying season length or timing.)

### *7.4.3.6 Hatchery Strategy*

The regional hatchery described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River spring Chinook salmon. Goals for spring Chinook salmon include using hatchery broodstocks to reestablish populations that have been extirpated (the Hood) or whose access to spawning and rearing habitat has been blocked by hydropower dams (the upper Cowlitz, North Fork Lewis, and Cispus populations and, potentially, the White Salmon). In general, reducing hatchery impacts on natural-origin spring Chinook salmon will be accomplished by (1) changing hatchery practices related to broodstock selection and management, numbers of releases, and locations and timing of acclimation and releases, and (2) physically excluding hatchery-origin fish from natural spawning areas by using weirs, traps, or other measures. For the Sandy and Hood populations, lessening the effects of hatchery-origin fish on naturally produced fish is expected to provide greater benefit than any other general category of action.

Details of how the hatchery strategy will be implemented in each spring Chinook salmon stratum will be developed as part of the transition schedules, but the subsections below provide some information.

**Cascade Spring Chinook Salmon Hatchery Strategy**

The hatchery strategy for the Cascade spring Chinook stratum centers on using hatchery spring Chinook salmon to reestablish the Upper Cowlitz and Cispus populations in historically accessible habitats in the Cowlitz subbasin and to reestablish the North Fork Lewis population in historically accessible habitats in the Lewis subbasin. (The Tilton population is targeted to be maintained at very low persistence probability, in part because of relatively poor habitat quality.) For the Kalama and Sandy populations, hatchery strategies will be targeted at reducing impacts on naturally spawning fish while continuing to produce spring Chinook salmon that provide fish for harvest. No hatchery spring Chinook salmon are released into the Toutle subbasin.

In the Cowlitz and Lewis systems, outplanting of hatchery-origin juveniles and adults is considered the initial stage of reintroduction. In this stage, broodstock choices are limited to existing hatchery stocks. In the Cowlitz, the Cowlitz hatchery broodstock has had negligible out-of-basin influence and is considered consistent with the original Cowlitz naturally spawning stock (LCFRB 2010a). Hatchery fish will be used to (1) reintroduce natural production in appropriate areas of the basin and adjacent tributary streams, (2) develop a local broodstock to reestablish historical diversity and life history characteristics, and (3) provide fishery mitigation in a manner that does not post significant risks to natural populations as they rebuild (LCFRB 2010a). The reintroduction program will include development of a biologically appropriate relationship and management strategy for hatchery and wild broodstock over time (LCFRB 2010a). Other considerations will include the timing of juvenile releases to minimize impacts to natural-origin fish (LCFRB 2010a).

In the North Fork Lewis subbasin, the Lewis River spring Chinook salmon program will be used to reintroduce spring Chinook salmon upstream of the hydrosystem. The Lewis hatchery spring Chinook salmon broodstock was developed from outside stocks, principally Cowlitz spring Chinook salmon, but currently is sustained without transfer from other hatcheries. As part of the reintroduction programs, facilities and operational strategies for these hatchery programs will address space, broodstock development, rearing methods, transfer of fish, marking strategies, and monitoring and evaluation (LCFRB 2010a).

In the near term, managing fisheries to meet hatchery escapement goals in the Cowlitz and Lewis systems is critical because recovery of spring Chinook salmon in those systems depends on the success of hatchery reintroduction programs, including the ability to collect enough fish at the hatcheries to meet the needs of the reintroduction program. Managing fisheries to meet hatchery escapement goals is therefore a key near-term strategy that integrates both harvest and hatchery objectives. As the reintroduction proceeds and natural production is established above the dams, the hatchery programs may shift to integrated supplementation to reduce risks to reestablished natural populations (as a first priority) and to improve the fitness of the hatchery stock (as a secondary priority). A matrix will be developed to manage naturally spawning fish in the broodstock, adult escapement to natural production areas and to the hatcheries, and hatchery fish on the spawning grounds (LCFRB 2010a).

To minimize potential predation on subyearling fall Chinook and chum salmon, the Washington management unit plan also calls for hatchery spring Chinook salmon release strategies that encourage rapid migration through the lower Cowlitz and Lewis; these strategies include volitional release, optimum release size, and release downstream of principal chum rearing areas (LCFRB 2010a).

In the Kalama and Sandy subbasins, hatchery programs will continue to produce fish for harvest concurrent with efforts to reduce impacts of hatchery fish on the natural populations. The spring Chinook salmon hatchery program in the Kalama is operated for fishery enhancement but with a dual supplementation objective: spring Chinook salmon that exceed broodstock needs are released above lower Kalama Falls to spawn naturally. Here, hatchery strategies will focus on (1) developing protocols regarding how many fish to pass upstream and (2) integrating hatchery and wild broodstock in the

future after wild production is established. In the Sandy subbasin, ODFW will implement actions designed to meet the pHOS target of 10 percent or less established by ODFW for populations in Oregon targeted for high persistence probability. These actions will include acclimation practices to reduce straying, use of flows to attract more fish to the hatchery, and, potentially, the use of a trap to sort hatchery-origin fish within Cedar Creek and/or at the acclimation facilities. The Sandy spring Chinook salmon program formerly was an integrated hatchery program and now is being operated as a segregated program. ODFW intends to develop a matrix to govern take of natural-origin adults for inclusion in hatchery broodstock once the population has recovered to levels that can support an integrated hatchery program. Achieving the pHOS target for the Sandy spring Chinook salmon population is a high priority because the Sandy is one of the healthiest spring Chinook populations in the ESU. If the target has not been achieved by the year 2022, NMFS will urge other means of reducing pHOS, such as reducing hatchery smolt releases or moving production to another subbasin.

**Gorge Spring Chinook Salmon Hatchery Strategy**

The hatchery strategy for the Gorge spring Chinook stratum involves the continuation of hatchery reintroduction efforts in the Hood subbasin, and a potential hatchery reintroduction program in the White Salmon subbasin now that Condit Dam has been removed. (The dam was breached in October 2011 and completely removed in September 2012.)

The historical spring Chinook salmon population in the Hood subbasin is considered extirpated, and Deschutes river stock (an out-of-ESU stock) is being used for a hatchery reintroduction program.[50] The recovery strategy calls for the program to continue and eventually be developed into an integrated hatchery/natural program. Specific strategies include moving toward in-basin rearing of hatchery spring Chinook salmon for better local adaptation of the Deschutes stock, working with the Confederated Tribes of Warm Springs to evaluate reintroduction and explore alternatives if the existing program is not successful, working with the Confederated Tribes of Warm Springs to develop a sliding scale for take of wild spring Chinook salmon broodstock for the integrated hatchery program, and installing an adult fish ladder and fish trap at Moving Falls to remove stray hatchery spring Chinook salmon from natural spawning areas.[51] The recovery strategy also includes reevaluation of the program at some point and exploration of alternatives (including alternative broodstock) if the current program is not successful.

The historical spring Chinook salmon population also is extirpated in the White Salmon subbasin because until recently Condit Dam, which is operated by PacifiCorp, has blocked access to virtually all historical spawning habitat. Under the terms of a 1999 FERC decommissioning agreement and a 2006 Biological Opinion, PacifiCorp breached Condit Dam in October 2011 and removed the dam in 2012. The White Salmon Working Group, which is composed of federal, state, and tribal fisheries managers as well as

[50] Some natural production is occurring in the Hood subbasin. At this time, the origin of that natural production is unknown.

[51] Note that ODFW 2010, p. 270, action ID 300 - HD, describes plans for a floating weir; subsequently, managers determined that a fish ladder and trap were more appropriate in this location.

representatives of PacifiCorp, recommended that, once the dam has been removed, natural escapement and production be monitored over a 4- to 5-year period, at which point the need and suitability for hatchery supplementation would be evaluated. If hatchery supplementation is needed, the working group has recommended that an integrated Klickitat hatchery spring Chinook salmon stock be developed and used as the brood source for juvenile release into the White Salmon subbasin.

The working group has noted that the 4- to 5-year monitoring period also will allow time to explore production capacity at the Klickitat Hatchery and develop the integrated spring Chinook salmon broodstock. The working group determined that the Klickitat Hatchery spring Chinook salmon program would be the best source of broodstock for reintroduction to the White Salmon, even though it is not part of the Lower Columbia River Chinook salmon ESU. Two other potential broodstock sources are the Lewis River hatchery spring Chinook salmon program in Washington and the Sandy River spring Chinook salmon program in Oregon. The Lewis River program was excluded from consideration for use in the White Salmon because it is needed for reintroduction efforts in the Lewis subbasin, and production in the Sandy River is constrained by broodstock collection and funding shortfalls (NMFS 2013).

In both the Hood and White Salmon subbasins, managers are either using (in the Hood) or considering using (in the White Salmon) out-of-ESU broodstock for reintroduction efforts. In general, these subbasins are in a transition area between the Lower Columbia and Mid-Columbia ESUs. The Deschutes population appears more aligned with the Mid-Columbia ESU and the Hood population with the Lower Columbia ESU, although geographically these subbasins are clearly part of a transitional area. There has been discussion among NMFS scientists about whether to recommend assigning populations in the Klickitat and White Salmon subbasin to the Lower Columbia or Mid-Columbia ESU. In its most recent 5-year review, NMFS noted the transitional nature of this area and that it would be reasonable to assign the Klickitat spring Chinook population to either ESU but recommended maintaining the existing ESU boundaries (75 *Federal Register* 50448). In addition, options for broodstock in the White Salmon and Hood subbasins are limited by extirpations and other factors.

In the case of the Hood population, NMFS is supportive of efforts to reestablish natural production in the Hood subbasin. As noted above, the current hatchery program in the subbasin uses broodstock from the adjacent Deschutes River hatchery program, a Mid-Columbia ESU stock. The natural stock restoration strategy for the Hood River should include periodic genetic assessments to determine whether there are indications of local adaptation and/or contributions representative of the Lower Columbia fall Chinook lineage. NMFS will work with co-managers throughout the implementation and adaptive management process to consider options for incorporating fish from the Lower Columbia Chinook salmon ESU into the Hood River population and to evaluate the most appropriate ESU membership of this population.

NMFS also supports efforts to reestablish natural production in the White Salmon subbasin, either through recolonization or through hatchery reintroduction, as appropriate, now that Condit Dam has been removed. (The dam was breached in October 2011 and completely removed in September 2012.) Because NMFS noted in its

most recent 5-year review (76 *Federal Register* 50448) that it would be reasonable to reassign the Klickitat population to either the Middle Columbia or the Lower Columbia River Chinook salmon ESU, the use of Klickitat stock for reintroduction in the White Salmon subbasin provides a more fluid situation in terms of ultimate ESU membership than does the use of Deschutes stock in the Hood subbasin. As in the Hood, NMFS expects that future 5-year reviews will reevaluate the most appropriate ESU membership for Klickitat and White Salmon populations.[52]

#### *7.4.3.7 Predation Strategy*

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia ESUs, including spring Chinook salmon.

#### *7.4.3.8 Critical Uncertainties*

Each aspect of the spring Chinook salmon recovery strategy has a number of critical uncertainties. For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to the Lower Columbia River spring Chinook salmon recovery strategy include the following:

- Effective methods of providing adequate downstream passage efficiency for juveniles migrating past tributary dams
- Effectiveness of natural recolonization (White Salmon) and hatchery reintroduction programs (Cowlitz, North Fork Lewis, Hood) and the pace at which these populations become functioning and self-sustaining; appropriate stock to use where reintroduction is necessary
- Productivity of reintroduced stocks in upper portions of subbasins
- Effectiveness of efforts to reduce straying in the Sandy and Hood subbasins now that Marmot and Powerdale dams have been removed
- Short-term and long-term survival benefits and risks at the population scale as a result of changes in hatchery production, changes in hatchery operation, and under various harvest rates
- How to reduce the risks of harvest of very small populations while still maintaining harvest opportunities on hatchery-origin fish

[52] The NMFS Recovery Implementation Science Team is currently developing a two-part report on the subject of reintroductions in the Columbia River Basin. The first part will address general principles for planning and implementing a reintroduction effort for anadromous salmonids. The second part will evaluate the biological benefit of a reintroduction in Columbia Basin regions from which anadromous salmonids have been extirpated. The final report is expected in 2012.

- Adequacy of actions to protect and restore watershed processes in maintaining habitat quality in upper basins (where spring Chinook salmon spawn) in the face of climate change

- Degree of pinniped predation on spring Chinook salmon in the Columbia River estuary

- The historical role of the Gorge populations and the appropriate persistence probabilities for these populations

- Most appropriate boundary between the Mid-Columbia and Lower Columbia river Chinook salmon ESUs[53]

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10 additional discussion among local recovery planners and NMFS staff will be needed to finalize future research priorities for Lower Columbia River steelhead.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the *Lower Columbia Fish Recovery Board completed the Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above also does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the spring Chinook salmon recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

[53] In its 2011 5-year review (NMFS 2011b), NMFS discussed uncertainties regarding the most appropriate boundary between the Mid-Columbia and Lower Columbia River ESUs. NMFS stated that, given the transitional nature of the Klickitat River Chinook salmon population, it might be reasonable either to reassign that population from the Middle Columbia to the Lower Columbia River Chinook salmon ESU or to maintain the existing ESU boundary. NMFS recommended maintaining the existing boundary but will reexamine the issue in future 5-year reviews as new information becomes available.

# 7.5 Fall Chinook Salmon Analysis: Limiting Factors, Threat Reductions, and Recovery Strategies

## 7.5.1 Fall Chinook Salmon Limiting Factors

The tule fall Chinook salmon component of the Lower Columbia River Chinook salmon ESU is limited by a combination of factors: widespread habitat degradation in both tributaries and the Columbia River estuary; a history of high harvest rates and large-scale hatchery production, with associated population depletions, reductions in productivity, and loss of genetic diversity; the effects of tributary and mainstem dams on critical downstream habitat; and predation by native fish, birds, and marine mammals. In addition, the productivity and diversity of fall Chinook salmon continue to be affected by ongoing straying of hatchery fish, and harvest impacts continue to be significant. For some populations, spatial structure is constrained by dams; for many more populations, spatial structure is constrained by urban, agricultural, and transportation development in lowland areas; development also contributes to losses in abundance as habitat quality is reduced.

Table 7-7 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River fall Chinook salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4). In addition, in Table 7-7, NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[54] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the White Salmon plan and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts, and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). For populations that historically spawned in the White Salmon subbasin, NMFS staff inferred primary and secondary designations based on discussion in the Washington

[54] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

and White Salmon management unit plans (LCFRB 2010a, NMFS 2013). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting Lower Columbia River fall Chinook salmon, including magnitude, spatial scale, and relative impact, see the management unit plans (LCFRB 2010a, Chapter 3 and various sections of Volume II; ODFW 2010, pp. 116 to 128; and NMFS 2013, Chapter 5).[55] For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary and the "crosswalk" tables that NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 7.5.2 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

[55] Limiting factors shown in the table for the White Salmon population reflect information from both the Washington (LCFRB 2010a) and White Salmon (NMFS 2013) management unit plans.

**Table 7-7**

*Baseline Limiting Factors and Threats Affecting LCR Fall Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast Fall | Cascade Fall | Gorge Fall |
|---|---|---|---|---|---|
| **Tributary Habitat Limiting Factors** | | | | | |
| Riparian Condition | Past and/or current land use practices | All | Secondary for Elochoman juveniles, primary for juveniles in all other populations | Secondary for Washougal juveniles, primary for juveniles in all other populations | Secondary for White Salmon juveniles, primary for juveniles in all other populations |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Secondary for Elochoman juveniles, primary for juveniles in all other populations | Secondary for Washougal juveniles, primary for juveniles in all other populations | Secondary for White Salmon juveniles, primary for juveniles in all other populations |
| Peripheral and Transitional Habitats: Side Channel and Wetland Conditions | Past and/or current land use practices/ transportation corridor | All | Secondary for Elochoman juveniles, primary for juveniles in all other populations | Secondary for Washougal juveniles, primary for juveniles in all other populations | Primary for Upper and Lower Gorge and Hood juveniles |
| Peripheral and Transitional Habitats: Floodplain Conditions | Past and/or current land use practices/ transportation corridor | All | Secondary for Elochoman juveniles, primary for juveniles in all other populations | Secondary for Washougal juveniles, primary for juveniles in all other populations | Primary for Upper and Lower Gorge and Hood juveniles |
| Sediment Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for WA juveniles, secondary for juveniles in OR populations[56] | Secondary for OR and Washougal juveniles, primary for juveniles in all other WA populations | Primary for White Salmon juveniles,[57] secondary for Hood juveniles |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dams | A,P,D | Primary for juveniles in WA populations | Primary for Toutle, Coweeman, Kalama, and Lewis juveniles, secondary for Clackamas (land use and dams), Sandy, Salmon Creek, and Washougal juveniles. | |

[56] This distinction is likely an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in sediment conditions in tributary streams or their effects on fall Chinook populations.

[57] The designation of sediment conditions as a primary limiting factor for White Salmon fall Chinook juveniles is based on presumed high fine sediment loads delivered from the former lakebed to the lower river, now that Condit Dam has been removed. The White Salmon management unit plan notes that the net effect of the removal of Condit Dam on habitat will need to be assessed (see Table 5-2 of NMFS 2013)..

**Table 7-7**

*Baseline Limiting Factors and Threats Affecting LCR Fall Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast Fall | Cascade Fall | Gorge Fall |
|---|---|---|---|---|---|
| Water Quantity (Flow) | Dams, land use, and water withdrawals for irrigation, municipal uses, and hatchery operations | All | Primary for Youngs Bay and Big Creek, and Scappoose juveniles, secondary for Grays/Chinook adults, secondary for juveniles in all other populations | Secondary for juveniles in all populations | Secondary for Upper and Lower Gorge and Hood juveniles (land use and dams); primary for Hood juveniles (irrigation withdrawals) |
| **Estuary Habitat Limiting Factors[58]** | | | | | |
| Toxic Contaminants | Agricultural chemicals, urban and industrial practices | A,P,D | Secondary for juveniles in all populations | | |
| Food[59] (Shift from macrodetrital- to microdetrital-based food web) | Dam reservoirs | All | Secondary for juveniles in all populations | | |
| Peripheral and Transitional Habitats: Estuary Condition | Past and/or current land use practices, transportation corridor, mainstem dams | All | Primary for juveniles in all populations | | |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | | |
| Sediment Conditions | Past and/or current land use practices/transportation corridor, dams | All | Primary for juveniles in all populations | | |

[58] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 7.4.1.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River fall Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[59] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

**Table 7-7**

*Baseline Limiting Factors and Threats Affecting LCR Fall Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast Fall | Cascade Fall | Gorge Fall |
|---|---|---|---|---|---|
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dam reservoirs | A,P,D | Secondary for juveniles in all populations | | |
| Water Quantity (Flow) | Columbia River mainstem dams | All | Primary for juveniles in all populations | | |
| **Hydropower Limiting Factors** | | | | | |
| Habitat Quantity (Access) | Bonneville Dam | All | | | Secondary for adults and juveniles in all populations |
| Habitat Quantity (Inundation) | Bonneville Dam | All | | | Primary for Upper Gorge adults and juveniles, secondary for Hood juveniles and White Salmon adults |
| Habitat Quantity (Access) | Tributary Dams | All | | Primary for Upper Cowlitz adults and juveniles, secondary for Sandy juveniles | Primary for White Salmon adults and juveniles, secondary for Hood adults and juveniles |
| **Harvest Limiting Factors** | | | | | |
| Direct Mortality | Fisheries | A,D | Primary for adults in all populations | Primary for adults in all populations | Primary for adults in all populations |
| **Hatchery Limiting Factors** | | | | | |
| Food[60] | Smolts from all Columbia Basin hatcheries competing for food and space in the estuary | All | Secondary for juveniles in all populations | | |
| Population Diversity | Stray hatchery fish interbreeding with wild fish | A,P,D | Primary for adults in all populations | Secondary for Coweeman adults, primary for adults in all other populations | Secondary for White Salmon adults, primary for adults in all other populations |
| **Predation Limiting Factors** | | | | | |
| Direct Mortality | Land use | A,P,D | Secondary for juveniles in all populations | | |

[60] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS 2011a and LCFRB (2010) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

**Table 7-7**

*Baseline Limiting Factors and Threats Affecting LCR Fall Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast Fall | Cascade Fall | Gorge Fall |
|---|---|---|---|---|---|
| Direct Mortality | Dams | A,P,D | | | Secondary for Upper Gorge and Hood juveniles (non-salmonid fish) |

### *7.5.1.1 Tributary Habitat Limiting Factors*

Impaired side channel and wetland conditions, along with degraded floodplain habitat, have significant negative impacts on juvenile tule fall Chinook salmon throughout the ESU and are identified as primary limiting factors for all populations except the Elochoman/Skamokawa, Washougal, and White Salmon, where they are identified as secondary factors. Extensive channelization, diking, wetland conversion, stream clearing, and, in some subbasins, gravel extraction have barred tule Chinook salmon from historically productive habitats and simplified much of the remaining tributary habitats, weakening watershed processes that are essential to the maintenance of healthy ecosystems. Degraded riparian conditions and channel structure and form issues are also a primary limiting factor for all populations except the Elochoman/Skamokawa, Washougal, and White Salmon, where they are identified as secondary factors. The lack of large woody debris and appropriately sized gravel in the remaining accessible tributary habitat has significantly reduced the amount of suitable spawning and rearing habitat for tule fall Chinook salmon.

Sediment conditions are identified as a primary limiting factor for all Washington populations except the Washougal (for which they are considered a secondary limiting factor) and are identified as a secondary limiting factor for the Oregon portion of the ESU.[61] The high density of forest and rural roads throughout the area, as well as timber harvest practices and other land use patterns on unstable slopes adjacent to riparian habitat, contributes to an abundance of fine sediment in tributary streams.[62] The resulting excess fine sediment covers spawning gravel, limiting egg development and incubation, and increases turbidity. In addition, water quality, specifically elevated water temperature brought about through land use, lack of functioning riparian habitat, and dam reservoirs, is a primary limiting factor for most Washington populations, along with the Clackamas and Sandy populations.

In the Coast fall Chinook stratum, tributary habitat limiting factors are largely the same as those described above for fall Chinook salmon as a whole. However, for the Youngs Bay, Big Creek, and Scappoose tule fall Chinook salmon populations, water quantity issues related to altered hydrology and flow timing also have been identified as a

[61] This distinction most likely is an artifact of differences in the limiting factor assessment methodologies used by Oregon and Washington and not an actual physical difference in sediment conditions in tributary streams or their effects on Chinook populations.

[62] By itself, road density is not necessarily a good measure of delivery of fine sediment to streams.

primary limiting factor. These water quantity issues are caused by land use practices on upland slopes that have reduced soil stability and vegetative cover, increased impermeable surfaces, and altered drainage systems, resulting in altered water storage and delivery to streams. Many stream systems have higher peak flows and lower base flows than they did historically (ODFW 2010). Past and current land uses in Coast ecozone watersheds have led to these conditions. Private and state forest land predominates in the upper reaches of these watersheds. Lower reaches are mostly in agricultural and rural residential use and have been extensively modified by bank stabilization, levees, and tide gates.

For the Cascade fall Chinook stratum, tributary habitat limiting factors are largely the same as those described above for fall Chinook salmon as a whole, except that spawning by the Clackamas, Sandy,[63] and Cowlitz fall Chinook salmon populations is also negatively by impaired gravel recruitment related to tributary dams. Land uses that have led to the conditions limiting habitat productivity in this stratum include forest management and timber harvest, agriculture, rural residential and urban development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development, especially in the Salmon Creek and lower Clackamas subbasins. The Oregon management unit plan notes that in the Clackamas subbasin, high water temperatures are attributed in part to hydropower reservoirs.

A unique issue in the Cascade fall Chinook stratum is legacy effects in the Toutle subbasin of the 1980 Mount St. Helen's eruption. The North Fork Toutle in particular was heavily affected by sedimentation from the eruption. A sediment retention structure was constructed on the North Fork Toutle in an attempt to prevent continued severe sedimentation of stream channels and associated flood conveyance, transportation, and habitat degradation problems. The structure currently blocks access to as many as 50 miles of habitat for anadromous fish. Although fish are transported around the structure via a trap and haul system, the structure remains a source of chronic fine sediment to the lower river; this reduces habitat quality and has interfered with fish collection at the base of the structure.

In the Gorge fall Chinook stratum, tributary habitat limiting factors are largely the same as those described above for fall Chinook salmon as a whole, save for some unique water quantity and habitat issues. Water quantity problems caused by irrigation withdrawals and low-head hydro diversions have been identified as primary limiting factors for the Hood population. Degraded habitat quality resulting from transportation corridor development and maintenance is considered a primary threat for the Upper and Lower Gorge populations and for Hood juveniles. These limiting factors result from past and current land uses that include a mix of private, state, and federal forest land in the upper mainstem and headwater reaches of the Gorge subbasins, and transportation

[63] Gravel recruitment may have improved since the removal of Marmot and Little Sandy dams in 2009; however, the Oregon management unit plan also identifies gravel recruitment as a result of the city of Portland's water supply system in the Bull Run watershed as a secondary limiting factor for the Sandy fall Chinook populations (ODFW 2010, p. 116).

and rural residential land uses, with some urban development, in lower mainstem and tributary reaches. Highway and transportation corridors run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes. Upper Gorge fall Chinook salmon also face habitat issues caused by inundation from Bonneville Reservoir.

Habitat within the White Salmon subbasin was altered by the breaching of Condit Dam (in October 2011, with full removal in September 2012). Alterations include near-term negative effects from sediment release and scouring. Scientists and managers expect long-term positive effects as the result of restoration of natural flow regimes and sediment transport, but monitoring is needed to evaluate habitat and fish response to dam removal, and additional assessment of habitat limiting factors will be needed to refine understanding of limiting factors.

#### *7.5.1.2 Estuary Habitat Limiting Factors*[64]

Estuary habitat conditions are important for juvenile fall Chinook salmon, which spend considerable time rearing in the estuary. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, and reduced access to peripheral and transitional habitats such as side channels and wetlands also are identified as primary limiting factors for juveniles from all populations. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor—while juveniles' access to side channels and wetlands is impaired by these same land uses but also by flow alterations caused by mainstem dams.

Secondary limiting factors in the estuary that affect tule fall Chinook salmon are exposure to toxic contaminants (from urban, agricultural, and industrial sources) and elevated late summer and fall water temperatures, which are related to (1) land use

[64] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 7-7 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River fall Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs. Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations.[65] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

For the Coast stratum populations in particular, improvements to estuary habitat may be crucial. Habitat analysis indicates that populations in the Coast ecozone historically relied on wetland areas at the confluences of the tributaries and the mainstem Columbia (Northwest Fisheries Science Center 2010).

#### *7.5.1.3 Hydropower Limiting Factors*

Direct hydropower impacts are low on most Lower Columbia River fall Chinook salmon populations, with the exception of the Upper Cowlitz, the Sandy, and the Gorge stratum populations. Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River fall Chinook salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 7.5.1.2).[66] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. For the Upper Gorge, Hood, and White Salmon populations, which spawn above Bonneville Dam, passage issues at Bonneville and inundation of historical spawning habitat by Bonneville Reservoir are identified as secondary limiting factors.

There are no large tributary dams in the Coast ecozone, but tributary dams affect Cascade and Gorge fall Chinook salmon populations. In the Cascade fall Chinook stratum, impaired habitat access and passage caused by tributary hydropower are identified as a primary limiting factor for the Upper Cowlitz fall Chinook salmon population. The hatchery Barrier Dam in the Cowlitz subbasin prevents all volitional passage of anadromous fish above RM 49.5. Passage of downstream fry for the Sandy fall Chinook salmon population also was identified as a secondary limiting factor; however, the PGE Bull Run Hydroelectric Project (consisting of Marmot and Little Sandy dams) in the Sandy subbasin was removed in 2007-2008, so this limiting factor has been addressed for the Sandy fall Chinook population. There are no tributary hydropower facilities in the Coweeman, Toutle, Kalama, East Fork Lewis, Salmon Creek, or Washougal subbasins.[67] The Clackamas River Hydro Project was not identified as a

[65] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[66] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

[67] However, the North Fork Toutle sediment retention structure currently blocks access to as many as 50 miles of habitat for anadromous fish.

hydropower threat for the Clackamas fall Chinook salmon population, but the project does affect downstream habitat; these impacts are accounted for under the tributary habitat limiting factor. In Washington, the Merwin, Yale, and Swift dams block passage to the Upper North Fork Lewis (beginning with Merwin Dam at RM 20). However, recovery efforts for the Lewis River fall Chinook salmon population are focused in the East Fork and lower North Fork Lewis subbasins, so the Merwin, Yale, and Swift dams are not identified as a limiting factor for fall Chinook salmon. Spawning and rearing habitats for the Lower Cowlitz and Lewis River fall Chinook salmon populations are adversely affected by flow regulation in the Cowlitz and Lewis river hydropower systems, respectively (LCFRB 2010a).

In the Gorge fall Chinook stratum, tributary hydropower impacts were identified as a primary limiting factor for the White Salmon fall Chinook salmon population (because, until recently, Condit Dam has blocked all upstream passage on the White Salmon River) and a secondary limiting factor for the Hood population (because of impaired access to historical spawning habitat). Powerdale Dam on the Hood River was removed in 2010, so that limiting factor has been addressed. Condit Dam was breached in October 2012 and completely removed in September 2012, so that limiting factor also has been addressed. Tributary hydropower is not a limiting factor for the Lower Gorge or Upper Gorge populations. However, for the three tule fall Chinook salmon populations that spawn above Bonneville Dam (the Hood, White Salmon, and Upper Gorge), passage issues at the dam and inundation of historical habitat by Bonneville Reservoir are secondary limiting factors.

#### *7.5.1.4 Harvest Limiting Factors*

Harvest-related mortality is identified as a primary limiting factor for all tule fall Chinook salmon populations. Tule fall Chinook salmon harvest occurs primarily in Alaskan and Canadian ocean fisheries regulated under the U.S.-Canada Pacific Salmon Treaty. Additional harvest occurs in U.S. ocean commercial, tribal, and recreational fisheries off the Washington Coast and in mainstem Columbia River gillnet and recreational fisheries. Harvest impacts were as high as 69 percent during the years 1983 to 1993. Since then they have been lowered steadily and significantly. For example, from 1999 to 2006, harvest rate averaged 48 percent; tule fall Chinook salmon harvest rates recently have been further reduced—to 38 percent in 2009 and 2010 and 37 percent in 2011 (NMFS 2008c). Harvest impacts on the Youngs Bay and Big Creek populations are higher—estimated by ODFW to average 75 and 65 percent, respectively, from 1997 to 2007—as a result of terminal fisheries targeting hatchery-origin fish in those subbasins. The Upper Gorge, Hood, and White Salmon populations also are subject to slightly higher harvest rates than the average for the ESU because they are intercepted in Zone 6 tribal fisheries above Bonneville Dam.

#### *7.5.1.5 Hatchery-Related Limiting Factors*

Most fall Chinook salmon currently returning to lower Columbia tributaries are produced in hatcheries operated to produce fish for harvest. Hatchery production has been reduced from its peak in the late 1980s but continues to threaten the productivity of Lower Columbia River fall Chinook salmon. Population-level effects resulting from hatchery fish interbreeding with natural-origin fish are a primary limiting factor for all

populations. Hatchery straying, combined with past stock transfers, has likely altered the genetics of fall Chinook salmon populations and may have reduced diversity within the ESU. Out-of-ESU Rogue River bright fall Chinook salmon released into Youngs Bay to support terminal harvest have been recovered in the Grays River, potentially affecting genetics and diversity within that population. Productivity also has likely declined as a result of the influence of hatchery-origin fish. In addition, many scientists suspect that competition with or predation by hatchery-origin fall Chinook salmon affects natural population productivity.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

#### *7.5.1.6 Predation Limiting Factors*

Direct mortality from predation is a secondary limiting factor for all fall Chinook salmon populations. Anthropogenic changes to habitat structure have increased predator abundance and effectiveness and led to increased predation by Caspian terns, double-crested cormorants, and various other seabird species in the Columbia River estuary and plume. Predation by non-salmonid fish (primarily northern pikeminnows) throughout the freshwater portions of the lower Columbia mainstem, but primarily at Bonneville Dam and hatchery release locations, is a secondary limiting factor for Upper Gorge and Hood juvenile tule fall Chinook salmon populations.

### 7.5.2 Fall Chinook Salmon Baseline Threat Impacts and Threat Reduction Targets

Table 7-8 shows the estimated impact on each Lower Columbia River fall Chinook salmon population resulting from potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing mortality levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. Cumulative values (both baseline and target) are multiplicative rather than additive. The table also shows the percentage improvements in population productivity and abundance (i.e., the percentage improvement in survival) that is needed to achieve the target impacts and

corresponding population status.[68] For populations where the survival improvement needed is larger than 500 percent, Table 7-8 does not report the exact value, in part because the value is highly uncertain.[69]

As an example, the baseline status of the Grays/Chinook fall Chinook salmon population, circa 1999, has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 92.6 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 7.4 percent of the historical potential with no human impact. Tributary habitat, harvest, and hatchery impacts each accounted for reductions in population productivity of 40 percent or more, with corresponding reductions in abundance, spatial structure, and diversity. The Washington management unit plan identifies a recovery strategy involving significant reductions in the impact of several threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 40 percent to 16 percent (i.e., an approximately 120 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 92.6 percent at baseline to 81.1 percent at the target status. This change would translate into a 150 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for Washington populations reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for Oregon populations reflect conditions through 2004. Dam impacts for Washington populations reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for Oregon populations, the estimates in the "Dams" column of Table 7-8 reflect direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for Washington populations were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); Oregon recovery planners estimated that hatchery impacts were equivalent to one-half the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting

[68] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: $[(1\text{-}Cumulative_{Target})\text{-}(1\text{-}Cumulative_{Baseline})]/[1\text{-}Cumulative_{Baseline}] \times 100$. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

[69] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

concern about genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 7-8 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 7-8 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 7-8 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 7-8 reflect policy decisions and the methodologies and assumptions used by the different recovery planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of Chinook salmon exposed to that particular category of threats, whether or not they are exposed to threats in other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[70] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 7-8, the baseline impacts from harvest, hatcheries, and loss and degradation of tributary habitat are significant for every fall Chinook salmon population. Only for the Upper Cowlitz, Upper Gorge, and White Salmon populations does another threat category (hydropower) rise to the level of harvest, hatchery, and tributary habitat impacts. Estuarine habitat impacts likewise consistently affect all populations, although to a lesser degree than tributary habitat impacts.

[70] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

In the Coast and Cascade strata, much of the gains in fall Chinook salmon viability are targeted to be achieved through reductions in harvest, hatchery, and habitat impacts. This is the case for the Grays/Chinook, Elochoman/Skamokawa, Toutle, East Fork Lewis, Sandy, and Washougal populations. For the Scappoose population, target status is expected to be achieved primarily through reductions in hatchery and harvest impacts. In the Gorge stratum, some threat reductions are also targeted from hydropower actions, as the Upper Gorge, White Salmon, and Hood populations have been affected by dam passage issues at Bonneville, Powerdale, and Condit dams. (Powerdale Dam, on the Hood River, was removed in 2010; Condit Dam was breached in October 2011 and completely removed in September 2012).

Impacts from multiple threat categories will be needed for most populations if they are to achieve their target status. Exceptions are the Youngs Bay, Big Creek, Upper Cowlitz, and Salmon Creek populations. As stabilizing populations, the Youngs Bay, Upper Cowlitz, and Salmon Creek populations are not targeted for reductions in any threat impacts. (However, recovery actions will still be needed for these populations to remain at their baseline status of low [for Youngs Bay] or very low.) Both the Youngs Bay and Big Creek populations will be used to provide harvest opportunity through terminal fisheries targeting hatchery fish; consequently, the proportion of hatchery-origin spawners (pHOS) and harvest impacts in these populations are expected to remain high. The Salmon Creek population is not targeted for threat reductions because of the highly urbanized nature of the subbasin and the extent of habitat degradation there. In the Upper Cowlitz subbasin, spring Chinook salmon recovery efforts are the focus of the recovery strategy, so the Upper Cowlitz fall Chinook population is not targeted for improvement in status (although as of 2010, fall Chinook are being transported and released into the Upper Cowlitz).

Four of the 21 fall Chinook salmon populations are targeted for significant reductions in every threat category, including hydropower (in the form of dam removal or improvements in upstream and downstream passage). These populations are the Toutle, Upper Gorge, White Salmon, and Hood. Of these, the Toutle and Hood are designated as primary and the Upper Gorge and White Salmon as contributing. The Hood population is targeted for dramatic and almost certainly unattainable threat reductions (i.e., reducing all threat categories except hydropower to zero).[71]

Reductions in predation are also targeted to contribute to achieving recovery goals for fall Chinook salmon; however, net reductions in predation impacts are smaller than those for the habitat, hatcheries, and harvest categories because the impact of predation threats is less.

More information on threat reduction scenarios, including methodologies used to determine baseline and target impacts, is available in the management unit plans (ODFW 2010, pp. 151-177 and LCFRB 2010a, pp. 4-30 through 4-33, and 6-49 through 6-52).

[71] This is a function of the Oregon recovery planning team setting target status to meet recovery criteria, even if the criteria are likely to be unattainable because of intractable anthropogenic impacts. In addition, Oregon believes that the historical population structure designated in the Gorge stratum should be reassessed. For a discussion of this and other issues related to the Gorge strata and delisting criteria, see Sections 3.2.1 and 7.7.

**Table 7-8**

*Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Fall Chinook Salmon Populations*

| Population | Impacts at Baseline[72] | | | | | | | Impacts at Target | | | | | | | % Survival Improvement Needed[80] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[73] | Est[74] | Dams[75] | Harv[76] | Hat[77] | Pred[78] | Cumulative[79] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumulative | |
| **Coast Fall** | | | | | | | | | | | | | | | |
| Youngs Bay (OR) | 0.72 | 0.32 | 0.00 | 0.75 | 0.45 | 0.07 | 0.9757 | 0.72 | 0.26 | 0.00 | 0.70 | 0.45 | 0.04 | 0.9672 | 30 |
| Grays/Chinook (WA) | 0.40 | 0.23 | 0.00 | 0.65 | 0.50 | 0.09 | 0.9264 | 0.16 | 0.09 | 0.00 | 0.26 | 0.20 | 0.03 | 0.5611 | >500 |
| Big Creek (OR) | 0.80 | 0.32 | 0.00 | 0.65 | 0.45 | 0.06 | 0.9754 | 0.58 | 0.26 | 0.00 | 0.60 | 0.45 | 0.04 | 0.9344 | 170 |
| Eloch/Skam (WA) | 0.30 | 0.23 | 0.00 | 0.65 | 0.50 | 0.09 | 0.9142 | 0.21 | 0.17 | 0.00 | 0.46 | 0.35 | 0.06 | 0.7837 | 150 |
| Clatskanie (OR) | 0.99 | 0.32 | 0.00 | 0.60 | 0.45 | 0.07 | 0.9986 | 0.80 | 0.26 | 0.00 | 0.35 | 0.05 | 0.05 | 0.9132 | >500 |
| Mill/Aber/Germ (WA) | 0.40 | 0.23 | 0.00 | 0.65 | 0.49 | 0.10 | 0.9258 | 0.29 | 0.17 | 0.00 | 0.47 | 0.35 | 0.07 | 0.8112 | 150 |
| Scappoose (OR) | 0.80 | 0.32 | 0.00 | 0.60 | 0.45 | 0.07 | 0.9722 | 0.78 | 0.26 | 0.00 | 0.35 | 0.05 | 0.05 | 0.9045 | 240 |
| **Cascade Fall** | | | | | | | | | | | | | | | |
| Lower Cowlitz (WA) | 0.70 | 0.23 | 0.00 | 0.65 | 0.50 | 0.10 | 0.9636 | 0.64 | 0.21 | 0.00 | 0.60 | 0.46 | 0.09 | 0.9441 | 50 |

[72] Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

[73] Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

[74] Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

[75] Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

[76] Includes direct and indirect mortality.

[77] Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

[78] Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

[79] Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$. Minor differences from numbers in ODFW 2010 and LCFRB 2010a are due to rounding.

[80] Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target), using the following equation: $[(1-\text{Cumulative}_{\text{Target}})-(1-\text{Cumulative}_{\text{Baseline}})]/[1-\text{Cumulative}_{\text{Baseline}}] \times 100$. These cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts. For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 7.5.2. For the Oregon population designated as stabilizing (Youngs Bay), a survival improvement is shown because of improvements that are expected in tributary habitat, estuary conditions, and predation.

**Table 7-8**

*Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Fall Chinook Salmon Populations*

| Population | Impacts at Baseline[72] | | | | | | | Impacts at Target | | | | | | | % Survival Improvement Needed[80] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[73] | Est[74] | Dams[75] | Harv[76] | Hat[77] | Pred[78] | Cumulative[79] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumulative | |
| Upper Cowlitz (WA) | 0.80 | 0.23 | 1.00 | 0.65 | 0.50 | 0.10 | 1.0000 | 0.80 | 0.23 | 1.00 | 0.65 | 0.50 | 0.10 | 1.000 | 0[81] |
| Toutle (WA) | 0.60 | 0.23 | 0.05 | 0.65 | 0.50 | 0.10 | 0.9539 | 0.41 | 0.16 | 0.03 | 0.44 | 0.34 | 0.07 | 0.8348 | 260 |
| Coweeman (WA) | 0.50 | 0.23 | 0.00 | 0.65 | 0.23 | 0.10 | 0.9066 | 0.41 | 0.19 | 0.00 | 0.53 | 0.19 | 0.08 | 0.8326 | 80 |
| Kalama (WA) | 0.40 | 0.23 | 0.00 | 0.65 | 0.50 | 0.10 | 0.9272 | 0.31 | 0.18 | 0.00 | 0.51 | 0.39 | 0.08 | 0.8444 | 110 |
| Lewis (WA) | 0.40 | 0.23 | 0.00 | 0.65 | 0.50 | 0.11 | 0.9280 | 0.23 | 0.13 | 0.00 | 0.38 | 0.29 | 0.06 | 0.7228 | 290 |
| Salmon Creek (WA) | 0.90 | 0.23 | 0.00 | 0.65 | 0.50 | 0.11 | 0.9881 | 0.90 | 0.23 | 0.00 | 0.65 | 0.50 | 0.11 | 0.9880 | 0 |
| Clackamas (OR) | 0.82 | 0.32 | 0.00 | 0.60 | 0.45 | 0.07 | 0.9750 | 0.82 | 0.26 | 0.00 | 0.35 | 0.15 | 0.06 | 0.9308 | 180 |
| Sandy (OR) | 0.83 | 0.32 | 0.03 | 0.60 | 0.45 | 0.07 | 0.9771 | 0.57 | 0.26 | 0.00 | 0.35 | 0.15 | 0.06 | 0.8347 | >500 |
| Washougal (WA) | 0.30 | 0.23 | 0.00 | 0.65 | 0.50 | 0.11 | 0.9161 | 0.20 | 0.15 | 0.00 | 0.43 | 0.33 | 0.07 | 0.7585 | 190 |
| **Gorge Fall** | | | | | | | | | | | | | | | |
| L. Gorge — WA portion | 0.70 | 0.23 | 0.30 | 0.65 | 0.50 | 0.11 | 0.9748 | 0.35 | 0.11 | 0.15 | 0.33 | 0.25 | 0.06 | 0.7677 | >500 |
| L. Gorge — OR portion | 0.82 | 0.32 | 0.00 | 0.60 | 0.45 | 0.07 | 0.9750 | 0.59 | 0.26 | 0.00 | 0.35 | 0.30 | 0.06 | 0.8702 | 420 |
| U. Gorge — WA portion | 0.70 | 0.22 | 0.54 | 0.65 | 0.50 | 0.14 | 0.9838 | 0.35 | 0.11 | 0.27 | 0.33 | 0.25 | 0.07 | 0.8026 | >500 |
| U. Gorge — OR portion | 0.80 | 0.32 | 0.13 | 0.65 | 0.45 | 0.09 | 0.9793 | 0.58 | 0.26 | 0.13 | 0.40 | 0.30 | 0.07 | 0.8944 | 410 |
| White Salmon (WA)[82] | 0.70 | 0.22 | 0.54 | 0.65 | 0.50 | 0.14 | 0.9838 | 0.35 | 0.11 | 0.27 | 0.33 | 0.25 | 0.07 | 0.8026 | >500 |
| Hood (OR)[83] | 0.71 | 0.32 | 0.19 | 0.70 | 0.45 | 0.09 | 0.9760 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.1000 | >500 |

[81] The Upper Cowlitz population is a stabilizing population not targeted for improvements in any threat category. Because hydropower impacts are 100 percent for this population, the formula for percent survival improvement for these populations was modified to account for the 100 percent hydropower impacts (i.e., to avoid having to divide by zero).

[82] Baseline and target impacts for the White Salmon population are from LCFRB (2010a).

[83] Oregon's analysis indicates a low probability of meeting the delisting objective of high viability persistence probability for this population.

## 7.5.3 Fall Chinook Salmon Recovery Strategy

### *7.5.3.1 Strategy Summary*

The recovery strategy for the tule fall component of the Lower Columbia River Chinook salmon ESU is designed to restore the Coast and Cascade tule strata to a high probability of persistence and to improve the persistence probability of all four Gorge-stratum populations. The strategy involves transitioning from decades of management that allowed habitat degradation and emphasized hatchery production of fish for harvest (without adequate regard to effects on natural production) to management that supports a naturally self-sustaining ESU. This transition will be accomplished by addressing all threat categories and sharing the burden of recovery across categories. The most crucial elements are as follows:

1. Protect and improve the Coweeman and Lewis populations, which are currently performing the best, by ensuring that habitat is protected and restored, that the proportion of hatchery-origin spawners (pHOS) is reduced, and that harvest rates allow for gains in productivity to translate into continued progress toward recovery.

2. Fill information gaps regarding the extent of natural production and the extent of hatchery-origin spawners.

3. Focus recovery efforts on populations that have the greatest prospects for improvement; determine whether efforts to reestablish populations are needed.

4. Protect existing high-functioning habitat for all populations.

5. Implement aggressive efforts to improve the quality and quantity of both tributary and estuarine habitat.

6. Implement aggressive efforts to reduce the influence of hatchery fish on natural-origin fish.

7. Adjust harvest as needed to ensure appropriate increases in natural-origin abundance.

8. Assess habitat quantity, quality, and distribution.

Transition strategies will be developed for each primary population that specify (1) timelines and strategies for reducing hatchery-origin spawners, (2) benchmarks for habitat improvement, (3) expected population response, and (4) harvest adjustments as needed to ensure appropriate increases in natural-origin abundance. These strategies will include adaptive management that provides a pathway for addressing critical uncertainties and that establishes benchmarks and adaptive actions if benchmarks are not met.

Transition strategies for non-primary populations will be developed to protect them from deterioration while moving them from high pHOS, with little or no natural production, through a period that addresses short-term demographic risks and reduces

hatchery fractions while improving habitat conditions. Monitoring and evaluation will be critical in validating and, as appropriate, updating current assumptions regarding what is currently limiting the most poorly performing populations (i.e., assumptions about pHOS rates, the degree of local adaptation, the causes of the poor performance, and how the poorly performing populations contribute to the overall genetic diversity of their stratum and the ESU).

Very large improvements are needed in the persistence probability of most fall Chinook salmon populations if this component of the Lower Columbia River Chinook salmon ESU is to achieve recovery (see Table 7-4 for the target persistence probability for each fall Chinook salmon population and Figure 7-7 for the gaps between baseline and target status). Recovery prospects for fall Chinook salmon populations in the Gorge are constrained by very low abundance, limited habitat availability, and inundation of historically productive habitat by Bonneville Reservoir (LCFRB 2010a). As indicated in the delisting criteria (see Section 3.2), the recovery scenario for fall Chinook salmon does not meet the criteria for a high probability of persistence as defined by the WLC TRT; in addition, whether the recovery scenario for Gorge fall Chinook salmon can even be achieved is highly uncertain because of questions about the historical role of the Gorge populations and constrained opportunities for habitat restoration. To compensate for these limited recovery prospects, additional populations in the Coast and Cascade strata are prioritized for high persistence probabilities.

The recovery strategy for tule fall Chinook salmon is a long-term, "all-H" approach in which plan implementers begin work on all of the elements described above immediately and implement actions associated with each of the six threat categories simultaneously.[84] As part of a series of 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation). Recovery will require improvements in every threat category, even those improvements in Table 7-8 that are relatively small. Substantial actions are needed to improve tributary and estuarine habitat and reduce the effects of hatcheries, harvest, and hydropower; without significant improvements in all of these threat categories, the benefits of actions in any individual sector are unlikely to be fully realized and the expected threat reductions will not be achieved. Hatchery actions in particular are needed immediately to reduce impacts on natural-origin populations; however, the exact type and extent of actions will depend on the results of early monitoring to determine more clearly the actual pHOS rates among different populations. (Populations-specific pHOS rates are a critical uncertainty for fall Chinook salmon; see Section 7.5.3.8.) Harvest strategies also will be influenced by the results of monitoring. As natural production, abundance, and diversity eventually improve in populations that currently are performing poorly, harvest rates may need to be reevaluated to avoid impacts on these newly emerging weak stocks.

Monitoring and evaluation are particularly important in the short term to address critical uncertainties about Lower Columbia River tule Chinook salmon. Specific needs include improving information on fall Chinook escapements in the Clatskanie and

[84] Implementation of recovery actions to reduce threats in each category is already under way, although the scale of effort is less than that called for in this recovery plan.

Scappoose, identifying those habitat restoration strategies that have the most potential to improve production, and verifying assumptions about habitat conditions in key reaches in the priority populations (e.g., are we right to target fine sediment levels in spawning reaches as restoration priorities for poorly performing populations such as the Clatskanie and Elochoman/Skamokawa?).

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013).

#### *7.5.3.2 Tributary Habitat Strategy*

An aggressive, strategic approach is needed to protect and restore tributary and Columbia River estuary habitat, both of which are severely limiting for Lower Columbia River tule fall Chinook salmon. Fall Chinook salmon will benefit from the regional tributary strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific management actions that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions designed to protect or restore habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds.

For fall Chinook salmon, the management unit plans set a high priority on reducing the impacts of sediment on survival to emergence and on improving juvenile rearing habitats, including reconnecting or restoring side channels and marsh habitats that are particularly critical to juvenile rearing of tule Chinook salmon. Priority site-specific actions will focus on protecting, restoring, or creating lowland floodplain function, riparian function, and stream habitat complexity. Priority restoration projects will include those to create or improve access to off-channel and side-channel habitat (alcoves, wetlands, floodplains, etc.) and restore riparian areas and instream habitat complexity; this includes improving recruitment of large wood to streams. Estuary/tributary confluence areas may also be a focus of site-specific actions, as habitat analysis indicates that substantial numbers of naturally produced juvenile Lower Columbia River fall Chinook salmon spend considerable time in such habitats (Cooney and Holzer 2010).

Near-term habitat actions should focus on implementing high-priority tributary actions that have already been identified, completing recovery plan implementation schedules, developing a prioritization and sequencing framework for habitat actions, and completing additional assessment work as part of developing the aforementioned transition strategy. This assessment effort should include identification of the amount and distribution of extant marsh-type habitats that are currently inaccessible for juvenile rearing in the tributaries used by Lower Columbia River tule Chinook salmon, along with identification of milestones or expected trends in improved habitat conditions in high-priority tributary and intertidal areas. The subsections below summarize additional, stratum-specific tributary habitat strategies for tule fall Chinook salmon.

Ultimately, restoration of adequate habitat for tules will be challenging because of the high proportion of habitat in private ownership.

**Coast Fall Chinook Salmon Tributary Habitat Strategies**

In implementing the Lower Columbia River fall Chinook salmon habitat strategy in the Coast fall stratum, considerations include the following:

- Lowland areas are primarily in agricultural or rural residential use. These areas have been extensively modified by dikes, levees, bank stabilization, and tide gates; efforts to protect and restore habitat complexity will be priorities here. Actions will include breaching, lowering, or relocating dikes and levees where possible to improve access to off-channel habitats for juvenile fall Chinook salmon, particularly in the Clatskanie, Scappoose, Grays, and Elochoman/Skamokawa subbasins (ODFW 2010, LCFRB 2010a).

- Upland areas are predominantly state and private timber land; these lands must be managed to protect and restore watershed processes (for example, through implementation of Washington's habitat conservation plan for state-owned forest land).

- Sediment source analyses and implementation of actions to reduce sediment will be needed in most Coast-stratum tributaries.

In addition to the actions described as part of the regional strategy for tributary habitat, the Washington management unit plan calls for restoring passage at culverts and other artificial barriers in the Elochoman/Skamokawa subbasin (LCFRB 2010a). The Oregon plan identifies a need to investigate whether headwater springs in the Youngs Bay, Big Creek, Clatskanie, and Scappoose subbasins are drying up as a result of land management practices.

Assuming that the impacts of other threats are reduced to the levels shown in Table 7-8, the scale of habitat improvements needed for the Coast fall Chinook stratum ranges from minimal in the Youngs Bay and Scappoose subbasins to a 20 to 30 percent increase in the productive capacity of tributary habitat in most subbasins. In the Grays subbasin, habitat productivity is targeted to increase by just over 60 percent.

**Cascade Fall Chinook Salmon Tributary Habitat Strategies**

In implementing the Lower Columbia River fall Chinook salmon habitat strategy in the Cascade stratum, considerations include the following:

- In the lower reaches of most Cascade subbasins, including the Lower Cowlitz, Coweeman, North Fork Lewis, East Fork Lewis, Toutle, Salmon Creek, and Clackamas, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development, agricultural land, and, in some cases, gravel mining. Restoration of these areas will need to be balanced with the need to protect existing infrastructure and control flood risk.

- Upper portions of the East Fork Lewis, Washougal, Clackamas, and Sandy subbasins are primarily federal forest lands. Continued implementation of the Northwest Forest Plan will be crucial in protecting and restoring watershed processes in these areas.

- State or private forest land predominates in the upper portions of the Coweeman, Toutle, Kalama, North Fork Lewis, and Salmon Creek subbasins. These lands must be managed to protect and restore watershed processes (for example, through implementation of Washington's habitat conservation plan for state-owned forest land).

- The stratum includes the most heavily urbanized areas in the Columbia Basin. Managing the impacts of growth and development on watershed processes and habitat conditions will be key to the protection and improvement of habitat conditions for fall Chinook salmon in these areas.

In addition to the actions described as part of the regional strategy for tributary habitat, addressing passage barriers such as culverts will benefit fall Chinook salmon by restoring access to habitat in a number of locations, including the Lower Cowlitz, Kalama, and East Fork Lewis subbasins. (In some cases, additional assessment is needed to inventory and prioritize these blockages.) Addressing passage and sedimentation issues associated with the sediment retention structure on the North Fork Toutle River will be a key component for the Toutle population. Sediment issues in other watersheds will be addressed generally by restoring watershed processes and dealing with legacy road issues. In some cases (e.g., the Sandy), assessment to identify sediment sources is noted as a first step before additional actions can be taken. The Oregon management unit plan identifies a need to address flow issues in the Clackamas subbasin and incorporates a number of flow-related actions. In the Sandy subbasin, implementation of the city of Portland's Bull Run Water Supply habitat conservation plan will contribute significantly to the habitat improvements needed to achieve the recovery target.

Assuming that the impacts of other threats are reduced to the levels shown in Table 7-8, the scale of habitat improvements needed for Cascade fall Chinook stratum populations ranges from minimal (but with protection of well-functioning habitat) to just over 40 percent. The two stabilizing populations—Salmon Creek and Upper Cowlitz—are not targeted for improvements in habitat productivity, in the first case because production potential is low and in the second case because spring Chinook salmon recovery efforts in the Upper Cowlitz have been prioritized over fall Chinook salmon. The Lower Cowlitz is targeted for an 8 percent improvement in habitat productivity, and the Sandy, Toutle, Coweeman, Kalama, Washougal, and East Fork Lewis subbasins are targeted for habitat improvements on the order of 20 to 40 percent. Oregon estimated that, for the Clackamas population, existing habitat is adequate to achieve the targeted medium persistence probability, assuming that all other targeted threat reductions for that population are achieved. However, the Oregon plan notes that, because of multiple uncertainties, efforts should still be made to protect and restore habitat in the Clackamas subbasin.

**Gorge Fall Chinook Salmon Tributary Habitat Strategies**

In implementing the Lower Columbia River fall Chinook salmon habitat strategy in the Gorge stratum, considerations include the following:

- In the lower reaches of most Gorge tributary streams, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development and transportation infrastructure. For the Lower Gorge population, site-specific actions will include addressing or mitigating the impacts of the highway and railroad transportation corridors that run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes.

- Gorge populations occur in watersheds that are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.

In addition to the actions described as part of the regional strategy for tributary habitat, the Oregon management unit plan identifies a number of actions to restore natural flows that have been disrupted by irrigation withdrawals in the Hood subbasin. Restoring floodplain connectivity and function is called for at locations below Bonneville Dam; however, there is little opportunity to implement floodplain measures above Bonneville Dam because much mainstem floodplain habitat was inundated by Bonneville Reservoir. For this reason, habitat efforts above the dam will rely on other strategies.

In the White Salmon subbasin, the breaching of Condit Dam in October 2011 (full removal was completed in September 2012) created near-term negative effects in the habitat below the dam and the habitat within the footprint of the former reservoir because of sediment release and scouring. Long-term effects are expected to be positive because of restored natural flow and sediment transport regimes. The White Salmon management unit plan outlines four broad tributary habitat strategies: (1) gain information to identify and prioritize habitat actions, (2) when the dam is removed, restore mainstem habitat, (3) protect and conserve natural ecological processes, and (4) improve habitat in upriver reaches (NMFS 2013). In the near-term, evaluating the effects of the dam breaching and removal on habitat and performing additional assessment of habitat limiting factors are high priorities.

Assuming that the impacts of other threats are reduced to the levels shown in Table 7-8, reductions in baseline tributary habitat impacts needed to meet target statuses range from 50 percent for the Lower and Upper Gorge and the White Salmon subbasins to a complete elimination of anthropogenically enhanced tributary habitat-related mortality in the Hood subbasin. (The Oregon management unit plan acknowledges that this is unattainable.)

#### *7.5.3.3 Estuary Habitat Strategy*

Estuarine habitat improvements are critical for Lower Columbia River fall Chinook salmon, which are severely limited by a paucity of intertidal marshes and similar estuarine wetlands that tules rely on for spawning, refuge, and extended rearing.

Improvements to estuary habitat may be especially important for Coast-stratum fall Chinook populations; outmigrant trapping and habitat analyses indicate that populations in the Coast ecozone historically relied on wetland areas at the confluences of the tributaries and the mainstem Columbia as juvenile rearing areas (Northwest Fisheries Science Center 2010). In addition, substantial numbers of naturally produced juvenile Lower Columbia River fall Chinook salmon spend significant time in estuary/tributary confluence habitats (Cooney and Holzer 2010).

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Lower Columbia River fall Chinook salmon. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2.) The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). For fall Chinook salmon, the assessment process described as part of the regional strategy should include assessment of the tidal portions of tributaries and their confluence with the mainstem Columbia. (Recent NMFS modeling for selected Lower Columbia River tule populations indicates that such confluence habitat may be especially important for Coast- and Cascade-stratum populations [Northwest Fisheries Science Center 2010].) Developing implementation priorities for estuarine habitat actions also should include establishment of milestones or expected trends in improved habitat conditions in high-priority intertidal areas.

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of outmigrating juveniles leaving the Columbia River estuary. Oregon and Washington recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for fall Chinook salmon populations based on the estuary module and their own approaches to threat reductions (see ODFW 2010, Tables 6-13 and 6-21; LCFRB 2010a, Table 6-2).

Ultimately, restoring adequate habitat for tules in the Columbia River estuary will be challenging because of the high proportion of habitat in private ownership.

#### *7.5.3.4 Hydropower Strategy*

Because tule fall Chinook salmon are distributed low in tributary subbasins, reintroduction above tributary dam complexes is not critical to their recovery. However, the hydropower strategy includes actions to improve passage survival at tributary dams and reduce the effects of dam operation (e.g., flow management and water temperatures) on critical downstream habitats.

The strategy also includes measures to improve passage survival at Bonneville Dam for the Upper Gorge, Hood, and White Salmon populations and implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. NMFS estimates that survival of

Lower Columbia River fall Chinook salmon passing Bonneville Dam was 95.1 percent for juveniles from 2002 to 2009 and 96.9 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expects that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will improve juvenile fall Chinook salmon survival at Bonneville Dam by less than ½ percent, and that adult survival will be maintained at recent high levels (NMFS 2008a). Consequently, Oregon has not incorporated survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[85] The Washington management unit plan assumes that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement will aid adults and juveniles from all Lower Columbia River fall Chinook salmon populations originating above Bonneville Dam. For more on actions to improve mainstem dam passage, see the regional hydropower strategy in Section 4.3.2.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for fall Chinook salmon.

**Coast Fall Chinook Salmon Hydropower Strategies**

There are no tributary dams in the Coast ecozone, so the hydropower strategy for the Coast stratum is to implement the FCRPS flow management operations for spring migrants from the interior of the Columbia Basin; these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River fall Chinook salmon populations.

**Cascade Fall Chinook Salmon Hydropower Strategies**

The primary element of the hydropower strategy for Cascade fall Chinook salmon is to address downstream impacts of operation of hydropower facilities in the Cowlitz and Lewis subbasins. These changes will be implemented under the terms of FERC relicensing orders for Tacoma Power's Cowlitz River Project in 2004 and for PacifiCorp and the Cowlitz PUD's Lewis River Hydroelectric Projects in 2002. In addition, the removal of PGE's Bull Run Hydroelectric Project (which consisted of Marmot and Little

[85] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

Sandy dams) in the Sandy subasin in 2009 addressed downstream passage impacts for fry of the Sandy fall Chinook salmon population.

Recovery efforts for Chinook salmon in the Upper Cowlitz subbasin are focused on spring Chinook salmon, [86] while fall Chinook salmon recovery efforts are focused on the Lower Cowlitz population (targeted for medium-plus persistence probability) rather than on the Upper Cowlitz population (targeted to be maintained at very low persistence probability). Flow regimes from Cowlitz River hydropower system operations affect spawning and rearing habitat for the Lower Cowlitz fall Chinook salmon population, so the recovery strategy includes actions to maintain a flow regime, including minimum flow requirements, to enhance fall Chinook salmon spawning and rearing habitats in the Lower Cowlitz (LCFRB 2010a). While passage for fall Chinook salmon through the Cowlitz subbasin dams is not a primary focus of the recovery strategy, fall Chinook salmon are (in 2010) passed above Mayfield Dam into the Tilton subbasin and above Cowlitz Falls Dam into the Upper Cowlitz subbasin. Although the primary habitat for fall Chinook salmon in the Upper Cowlitz has been inundated, efforts are being made to reestablish some fall Chinook salmon spawning in the Upper Cowlitz.

In the Lewis subbasin, tule fall Chinook salmon occur in both the lower North Fork Lewis and the East Fork Lewis (where there are no hydropower dams), but the East Fork Lewis supports most of the production and, along with the lower North Fork, is the focus of recovery efforts.[87] As in the Cowlitz, hydroregulation on the Lewis River has altered the natural flow regime below Merwin Dam, affecting the quantity and quality of fall Chinook salmon spawning and rearing habitat. The Washington management unit plan includes a measure to operate the Lewis hydrosystem to provide appropriate flows for salmon spawning and rearing habitat. The operational plan for the Lewis River dams, in conjunction with fish management plans, should include flow regimes—including minimum flow and ramping rate requirements—that enhance the lower river habitat for fall Chinook salmon (LCFRB 2010a). Passage at the Lewis River dams is not part of the recovery strategy for Lewis River fall Chinook salmon.

**Gorge Fall Chinook Salmon Hydropower Strategies**

Tributary hydropower impacts for the White Salmon and Hood populations have been addressed by removing Condit and Powerdale dams, respectively. Condit Dam, operated on the White Salmon River by PacifiCorp, was breached in October 2011 and completely removed in September 2012, under the terms of a 1999 decommissioning agreement and a 2006 Biological Opinion. Removal reopens access to four miles of historical fall Chinook salmon habitat (55 percent of historical spawning habitat is above the dam) (NMFS 2013). Natural escapement and production will be monitored for 4 to 5 years; if adequate recolonization has not occurred by that time, appropriate hatchery adults and/or juveniles may be released into the White Salmon River. Powerdale Dam, on the Hood River and also operated by PacifiCorp, was removed in 2010 under the

[86] Barrier Dam and Mayfield Dam in the Cowlitz Basin prevent all volitional passage of anadromous fish above RM 49.5.
[87] In the North Fork Lewis Basin, three dams (Merwin, Yale, and Swift), beginning with Merwin Dam at RM 20, block passage to the upper North Fork Lewis.

terms of a settlement agreement reached in 2003. Benefits to fall Chinook salmon in the Hood River will include improved upstream and downstream migration; removal of the dam is expected to reduce hydropower-related impacts for the Hood fall Chinook salmon population from 18.7 percent to 13 percent (ODFW 2010). Tributary dams do not affect the Lower Gorge or Upper Gorge populations.

Actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will also provide slight improvements in juvenile survival for the three Gorge fall Chinook salmon populations that spawn above Bonneville Dam (see the regional hydropower strategy in Section 4.3.2).

#### *7.5.3.5 Harvest Strategy*

Consistent with the regional harvest strategy (see Section 4.5.2), the harvest strategy for Lower Columbia River fall Chinook salmon focuses on refining harvest management to further reduce impacts to naturally produced fish while maintaining harvest opportunities that target hatchery-produced fish. Harvest on Lower Columbia River tule Chinook salmon has been reduced from average highs of 69 percent during the years 1983 to 1993 to an average of 48 percent from 1999 to 2006, 38 percent in 2009 and 2010, and 37 percent in 2011 (NMFS 2008c). These changes have contributed to the harvest reductions called for in the Oregon and Washington management unit plans, both of which envision further reductions through a strategy of implementing mark-selective fisheries when feasible as a tool to sustain important fisheries, implementing abundance-based management when feasible, and applying weak-stock management principles.[88]

In terms of needed additional reductions, the Oregon management unit plan did not recommend specific harvest rates; instead, in its analyses it used 35 percent as a modeled, long-term average harvest rate and assumed that harvest actions such as abundance-based, weak-stock management and mark-selective commercial fisheries would be implemented. The Washington management unit plan recommends a phased harvest strategy involving lower near-term rates to reduce population risks until habitat improvements are achieved. Modeling in the Washington management unit plan shows a scenario in which harvest rates would be managed for benchmarks of 38 to 49 percent for the period between 1999 (the time of listing) and the year 2010, and rates of 33 to 38 percent from 2011 to 2022. (The benchmark range is a target to be met within the designated period and will be used to assess progress toward recovery. With respect to tule Chinook salmon, the 1999-2010 benchmark range of 38 to 49 percent was met by rates of 38 to 49 percent over most of the period.) The modeling also projects that harvest rates eventually would increase as the benefits of other recovery actions are realized and natural production improves. These modeling results are planning targets and not predictions of future harvest rates; managers will establish future harvest rates based on observed indicators in Lower Columbia River fall Chinook salmon populations.

NMFS' recent modeling (Northwest Fisheries Science Center 2010), which addressed all primary tule populations except the Toutle, indicates that, in the Cascade stratum, the Lewis, Washougal, and Coweeman populations would benefit somewhat from

[88] A critical question regarding weak stock management principles is how and when tule harvest will be based on the populations in the Coast stratum.

additional harvest reductions but would be at low demographic risk at harvest rates of up to 38 percent. In the Coast stratum, the Clatskanie, Scappoose, and Elochoman/Skamokawa populations appear to be sustained by hatchery straying under current conditions and modeling indicates they would be at high risk in the absence of hatchery augmentation, even at very low harvest rates. The Mill/Abernathy/Germany population would be at intermediate risk at intermediate harvest levels. Because few population-specific landscape habitat maps are available, the NMFS analysis applied tributary habitat assumptions derived for the East Fork Lewis River to all populations. Under that assumption set, the Hood population appears to be self-sustaining at a harvest rate of around 20 percent; however, the Oregon management unit plan discusses the unique nature of the Hood River drainage, including the dynamic nature of sediment conditions caused by glacial inputs and other factors, and is more pessimistic about the status of that population (ODFW 2010). The uncertainty in all of these predictions is substantial. The Oregon and Washington management unit plans both highlight the need for improved estimates of current spawning levels and habitat conditions for Lower Columbia River fall Chinook salmon populations. The Oregon management unit plan identifies evaluating and potentially updating available data series for the Clatskanie, Scappoose, and Hood River fall Chinook salmon populations as high-priority technical tasks. Incorporating drainage-specific tributary habitat information may substantially alter model projections.

NMFS will ensure that best available science continues to be used to determine harvest rates that, when combined with other threat reduction strategies, are likely to achieve positive growth rates and move populations to their target status over the long term. Near-term actions will evaluate and describe options for employing mark-selective fishing strategies in order to sustain fisheries while reducing fishery impacts on naturally produced Lower Columbia River tule Chinook salmon populations. Near-term actions also will include investigation of one or more options for predicting the abundance of natural-origin Lower Columbia River tule Chinook salmon (including the use of prior year returns) and incorporating abundance-driven management principles into Lower Columbia River tule harvest management.

The current harvest strategy is based on the assumption (supported by the results of Northwest Fisheries Science Center 2010 modeling) that the productivity of the poorly performing populations in the Coast stratum is so low that their extinction risk would remain high regardless of harvest rates. The Hood tule population presents an additional challenge for several reasons. First, there is a relatively high degree of uncertainty associated with the specific assumptions regarding current tributary habitat conditions incorporated into NMFS' modeling for the Hood population. In addition, the population's baseline persistence probability in these model runs is very low, the population is targeted for high persistence probability, and—because of harvest impacts in Zone 6 fisheries above Bonneville Dam—the Hood population is subject to exploitation rates higher than those for the Coast and Cascade strata.[89] In the future, as productivity begins to improve in populations that currently are performing poorly, NMFS, co-managers, and the management unit leads will evaluate whether harvest needs to be adjusted. Additional information will be needed to understand how harvest

[89] Harvest management provisions in Zone 6 have been established through the year 2017 under the *US v. Oregon* process. Harvest in Zone 6 is limited primarily by constraints on upriver fall Chinook and steelhead.

and other threats are affecting the ability of tule populations to achieve their recovery targets and appropriate strategies will need to be developed.

In ESA evaluations of hatchery and harvest actions, NMFS expects to analyze the combinations of effects of multiple actions when appropriate. For example, where hatchery production clearly is intended to support harvest, the synergistic effects of artificial production and harvest will need to be analyzed at the juvenile and adult life stages. This should include ecological interactions as well as genetic and other considerations.

**Coast Fall Chinook Salmon Harvest Strategies**

The ESU-level harvest strategy described above is expected to reduce harvest impacts on most populations in this stratum. As part of the strategy to direct harvest impacts away from other Lower Columbia River fall Chinook salmon populations, terminal fisheries targeting hatchery fish in Youngs Bay and Big Creek will continue, and those populations will continue to be subject to higher harvest rates than other fall Chinook salmon populations. Still, implementation of the ESU-level harvest strategy is expected to reduce harvest impacts on the Youngs Bay and Big Creek populations from 75 and 65 percent, respectively, to 70 and 60 percent (ODFW 2010).

**Cascade Fall Chinook Salmon Harvest Strategies**

The ESU-level harvest strategy described above is expected to reduce harvest impacts on all populations in this stratum.

**Gorge Fall Chinook Salmon Harvest Strategies**

The ESU-level harvest strategy described above is expected to reduce harvest impacts on all populations in this stratum.

#### *7.5.3.6 Hatchery Strategy*

The regional hatchery strategy described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River fall Chinook salmon. In general, pHOS will be reduced through a combination of removal of excess hatchery-origin fish at weirs,[90] shifts in production levels or locations, changes in hatchery practices, and mark-selective harvest. Some programs will be shifted to formal integrated programs, in which genetic hatchery impacts are reduced through inclusion of natural-origin fish in the broodstock. Because pHOS and its impact on the productivity of naturally spawning fish are key uncertainties for fall Chinook salmon, the management unit recovery plans propose monitoring to determine with more certainty the actual pHOS, while simultaneously moving ahead with actions to reduce the influence of hatchery fish to levels appropriate to each population (i.e., populations with a higher target persistence probabilities will be targeted for lower levels of influence), using techniques tailored to

[90] The ecological risks of weirs will also be considered. The Recovery Implementation Science Team (RIST) discussed potential benefits and ecological risks associated with use of weirs (Recovery Implementation Science Team 2009).

the circumstances of each population.[91] Transition schedules will recognize the differences between populations such as the Washougal, where strays are largely from a within-population tributary hatchery program, and the Lewis, where hatchery strays are also from an adjacent facility but presumably are present at much lower numbers than in some populations. Near-term priorities include conducting more detailed assessments of current spawning escapements and hatchery proportions in the Clatskanie and Scappoose populations, both of which are designated as primary. The historical-to-current spawner data series for these two populations are highly uncertain. Near-term priorities also include continuing the efforts already under way to shift production and install and operate weirs. In addition, NMFS believes that there is a need for studies of the potential effects hatchery introgression on productivity (such studies are rare for fall Chinook salmon). Long-term priorities include achieving the recovery targets for each population and reducing reliance on hatchery production for harvest or risk reduction as natural productivity improves.

Details of how the hatchery strategy will be implemented in each fall Chinook salmon stratum will be developed as part of the transition schedules, but the subsections below provide some information.

**Coast Fall Chinook Salmon Hatchery Strategies**

The preliminary intent of the Coast-stratum hatchery strategy includes maintaining the Youngs Bay and Big Creek subbasins as areas of hatchery production to support terminal fisheries targeting hatchery fish; consequently, pHOS in the Youngs Bay and Big Creek populations is expected to remain high, and the populations are targeted to be maintained at low persistence probabilities. Some fall Chinook salmon hatchery production will be shifted from Big Creek to Youngs Bay in an effort to reduce hatchery-origin spawners in the Clatskanie and, to a lesser degree, Scappoose subbasins. Existing weirs in both Youngs Bay and Big Creek will be used to pass natural-origin fish into sanctuary areas. The Clatskanie and Scappoose subbasins will remain areas where no hatchery fish are released. If pHOS in the Clatskanie remains higher than 10 percent, a trap may be installed to sort hatchery fish within 15 years.[92]

The Grays/Chinook, Mill/Abernathy/Germany, and Elochoman/Skamokawa subbasins also are expected to be maintained as areas where no hatchery fall Chinook salmon are released. No hatchery fall Chinook salmon have been released in the Grays subbasin since 1998 and none from the Abernathy fall Chinook salmon program since 1995. The Elochoman hatchery was closed in 2009. The proportion of hatchery-origin spawners in each subbasin needs to be reduced; hatchery strays in the Grays subbasin are believed to come primarily from the Rogue River bright fall Chinook stock used to produce fish for the Select Area fishery in Youngs Bay. As of late 2011, weirs were in use in the Grays, Washougal, Elochoman, Coweeman, and Toutle rivers to separate hatchery- from natural-origin fish.

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[91] For example, ODFW has established a target of 10 percent or less hatchery-origin spawners in natural spawning areas for populations targeted for high probability of persistence. WDFW will establish similar targets in its Conservation and Sustainable Fisheries Plan.

[92] The Oregon management unit plan did not incorporate an explicit contingency plan for the Scappoose basin.

### Cascade Fall Chinook Salmon Hatchery Strategies

Currently, no hatchery fish are released into the Coweeman, Lewis, or Salmon Creek subbasins in Washington or into the Clackamas or Sandy subbasins in Oregon, although fall Chinook salmon populations in these watersheds are affected by hatchery-origin spawners that stray from other areas within the Lower Columbia subdomain. These areas are expected to be maintained as areas with no hatchery releases, and recovery actions will focus on reducing the proportion of hatchery-origin spawners (pHOS) to levels appropriate to each population depending on its target status.

As of 2010, fall Chinook salmon were being released into the Upper Cowlitz subbasin as part of a reintroduction strategy, although they are not the focus of the recovery effort in that subbasin. In the Lower Cowlitz, Toutle, Kalama, and Washougal, hatchery programs currently produce and release fall Chinook salmon that are intended to support harvest, in part as mitigation for fall Chinook salmon production lost as a result of multiple factors in the Columbia Basin. In these programs hatchery recovery efforts will focus initially on developing integrated hatchery programs through actions such as separate management of hatchery and natural subpopulations, control of hatchery-origin fish into natural spawning areas, incorporation of natural-origin fish into hatchery broodstock (LCFRB 2010a). Specific approaches to broodstock and targets for proportions of hatchery-origin spawners and natural-origin broodstock will be developed for each population depending on its target status.

In the Sandy subbasin, stray rates already have been reduced significantly from baseline levels and currently are lower than the 30 percent identified for recovery (ODFW 2010). Further reductions in pHOS may be difficult.

### Gorge Fall Chinook Salmon Hatchery Strategies

Hatchery strategies for Gorge fall Chinook salmon will consist largely of changes in fishery enhancement programs to reduce hatchery impacts on natural-origin spawners. Actions may include separate management of hatchery and natural subpopulations and control of hatchery-origin fish into natural spawning areas. Specific targets for proportions of hatchery-origin spawners will be developed for each population depending on its target status.

For the Lower Gorge population, ODFW may install a weir and trap to reduce pHOS by separating natural- from hatchery-origin adults at Eagle Creek and Tanner Creek in Oregon. There are no hatcheries operating in the Washington Lower Gorge tributaries.

For the Upper Gorge population, Oregon will consider placing a trap at Herman Creek to sort hatchery fish. For the Washington portion of the Upper Gorge population and the White Salmon population, fall Chinook salmon from four federal hatcheries will continue to be released to provide for fishery enhancement (LCFRB 2010a).

#### *7.5.3.7 Predation Strategy*

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia River ESUs, including tule fall Chinook salmon.

#### *7.5.3.8 Critical Uncertainties*

Each aspect of the fall Chinook salmon recovery strategy has a number of critical uncertainties. For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to Lower Columbia River fall Chinook salmon include the following:

- Current level of natural productivity, hatchery fractions, sources of hatchery strays, loss and gain of reproductive fitness, and ecological interactions between hatchery-origin fish and natural-origin fish
- Effects of hatchery-origin fish on natural productivity at the population level, and whether there are density-dependent and/or predation effects in the Columbia River estuary
- Response in natural productivity to reductions in pHOS, and the time frame of that response
- Effectiveness of integrated hatchery programs in restoring the productivity of natural populations; availability of sufficient numbers of naturally produced fish for incorporation in the hatchery broodstock; validity of assumptions concerning natural fitness of hatchery-origin fish produced using natural broodstock
- Historical role of the Gorge populations and appropriate persistence probabilities, and abundance and productivity targets, for these populations
- Most effective recovery strategy for populations whose genetic diversity is low and that may not be locally adapted
- Appropriate stock to use (especially in terms of run timing) if reintroduction is necessary
- Effect of the distribution of intertidal habitats on the life history strategies of fall Chinook salmon[93]
- Locations of priority habitats for restoration, especially with respect to the distribution of intertidal habitats

[93] Recent modeling by NMFS (Northwest Fisheries Science Center 2010) for selected LCR tule populations indicates that "confluence habitat" (i.e., the tidal portions of tributaries and their confluence with the mainstem Columbia) may be especially important for coastal and Cascade populations.

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10, additional discussion among recovery planners and NMFS staff will be needed to finalize future research priorities for Lower Columbia River fall Chinook salmon.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the *Lower Columbia Fish Recovery Board completed the Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above also does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the fall Chinook salmon recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

Monitoring and evaluation are particularly important in the short term to address critical uncertainties about Lower Columbia River tule Chinook salmon, identify those habitat restoration strategies that have the most potential to improve production, and verify assumptions about habitat conditions in key reaches in the priority populations (e.g., are we right to target fine sediment levels in spawning reaches as restoration priorities for poorly performing populations such as the Clatskanie and Elochoman/Skamokawa?).

## 7.6 Late-Fall Chinook Salmon Analysis: Limiting Factors, Threat Reductions, and Recovery Strategies

### 7.6.1 Late-Fall Chinook Salmon Limiting Factors

Table 7-9 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River late-fall Chinook salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless noted otherwise, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4 and Appendix H). In addition, in Table 7-9 NMFS has rolled up the population-specific limiting factors to the stratum level—a process that also has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[94] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the estuary module did not. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting Lower Columbia River late-fall Chinook salmon, including magnitude, spatial scale, and relative impact, (see LCFRB 2010a, Chapter 3 and various sections of Volume II, and ODFW 2010, pp. 116-128). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 7.6.2 and provide a related but slightly different perspective on limiting factors. The threat

[94] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

**Table 7-9**

*Baseline Limiting Factors and Threats Affecting LCR Late-Fall Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Late Fall |
|---|---|---|---|
| **Tributary Habitat Limiting Factors** | | | |
| Riparian Condition | Past and/or current land use practices | All | Primary for Sandy juveniles, secondary for NF Lewis juveniles |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Primary for Sandy juveniles, secondary for NF Lewis juveniles |
| Peripheral and Transitional Habitats: Side Channel and Wetland Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for Sandy juveniles, secondary for NF Lewis juveniles |
| Peripheral and Transitional Habitats: Floodplain Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for Sandy juveniles, secondary for NF Lewis juveniles |
| Sediment Conditions | Past and/or current land use practices/ transportation corridor | All | Secondary for juveniles in both populations |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dams | A,P,D | Secondary for juveniles in NF Lewis |
| Water Quantity (Flow) | Dams, land use, irrigation, municipal, and hatchery withdrawals | All | Secondary for juveniles in both populations |
| **Estuary Habitat Limiting Factors**[95] | | | |
| Toxic Contaminants | Agricultural chemicals, urban and industrial practices | A,P,D | Secondary for juveniles in both populations |
| Food[96] (Shift from macrodetrital- to microdetrital-based food web) | Dam reservoirs | All | Secondary for juveniles in both populations |

[95] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 7.5.1.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River late-fall Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[96] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

**Table 7-9**

*Baseline Limiting Factors and Threats Affecting LCR Late-Fall Chinook Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Late Fall |
|---|---|---|---|
| Peripheral and Transitional Habitats: Estuary Condition | Past and/or current land use practices/transportation corridor, mainstem dams | All | Secondary for juveniles in both populations |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Secondary for juveniles in both populations |
| Sediment Conditions | Past and/or current land use practices/transportation corridor , dams | All | Primary for juveniles in both populations |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dam reservoirs | A,P,D | Secondary for juveniles in both populations |
| Water Quantity (Flow) | Columbia River mainstem dams | All | Primary for juveniles in both populations |
| **Hydropower Limiting Factors** | | | |
| Habitat Quantity (Access) | Bonneville Dam | All | |
| Habitat Quantity (Access) | Tributary dams | All | Secondary for Sandy juveniles |
| **Harvest Limiting Factors** | | | |
| Direct Mortality | Fisheries | A,D | Primary for adults in both populations |
| **Hatchery Limiting Factors** | | | |
| Food[97] | Smolts from all Columbia Basin hatcheries competing for food and space in the estuary | All | Secondary for juveniles in both populations |
| Population Diversity | Stray hatchery fish interbreeding with wild fish | A,P,D | Primary for Sandy adults |
| **Predation Limiting Factors** | | | |
| Direct Mortality | Land use | A,P,D | Secondary for juveniles in both populations |
| Direct Mortality | Dams | A,P,D | |

### *7.6.1.1 Tributary Habitat Limiting Factors*

Degraded riparian conditions caused by land uses past and present are a primary limiting factor for the Sandy late-fall Chinook salmon population and a secondary factor for the North Fork Lewis population. So, too, are channel structure and form issues, in the form of reductions in habitat complexity, diversity, and connectivity; changes in channel structure and form have resulted from past and current land uses, including the

[97] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS 2011a and LCFRB (2010) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

transportation corridor. Sediment conditions are a secondary limiting factor for both populations. The high density of forest and rural roads in the Lower Columbia subdomain contributes to an abundance of fine sediment in tributary streams used by late-fall Chinook salmon. The resulting excess fine sediment covers spawning gravel, limiting egg development and incubation.

Water quality—specifically elevated water temperature—is a secondary limiting factor for juveniles from the North Fork Lewis population of late-fall Chinook salmon. Water quantity issues related to altered hydrology and flow timing have been identified as secondary limiting factors for both populations. Impaired side channel and wetland conditions along with degraded floodplain habitat also have significant negative impacts on Lower Columbia River late-fall Chinook salmon, warranting mention as a primary limiting factor for the Sandy population and a secondary factor for the North Fork Lewis population.

#### *7.6.1.2 Estuary Habitat Limiting Factors*[98]

Estuary habitat conditions are important for juvenile late-fall Chinook salmon, which spend considerable time rearing in the estuary. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for both late-fall populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web.

Channel structure issues, in the form of reduced habitat complexity and diversity, are identified as a secondary limiting factor for juveniles from both populations, as is lack of access to peripheral and transitional habitats such as side channels and wetlands. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor—while juveniles' access to side channels and wetlands is impaired by these same land uses but also by flow alterations caused by mainstem dams. Other secondary limiting factors in the estuary that affect both late-fall bright populations are exposure to toxic contaminants (from urban, industrial, and agricultural sources) and elevated late summer and fall water

[98] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 7-9 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River late-fall Chinook salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs. Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for both populations.[99] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

#### *7.6.1.3 Hydropower Limiting Factors*

Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River late-fall Chinook salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 7.6.1.2).[100] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Tributary hydropower impacts in the form of impaired habitat access and passage were identified as a secondary limiting factor for Sandy late-fall Chinook salmon, with downstream fry passage being impaired by PGE's Bull Run Hydroelectric Project (consisting of Marmot and Little Sandy dams). This project was removed in 2009, so this limiting factor has been addressed. In the Lewis subbasin, the Lewis River hydroelectric project's effects on flow, sediment transport, and large wood supply were identified as limiting factors.

#### *7.6.1.4 Harvest Limiting Factors*

Harvest-related mortality is identified as a primary limiting factor for both populations. Harvest rates historically were around 54 percent but have dropped to approximately 36 percent since listing. The majority of the harvest affecting late-fall Chinook salmon takes place in ocean fisheries, although there is some harvest in non-treaty fisheries in the mainstem Columbia River below Bonneville Dam, and in the North Fork Lewis River.

#### *7.6.1.5 Hatchery-Related Limiting Factors*

Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish are identified as a secondary limiting factor for the Sandy population, which has an average pHOS of 25 percent. The North Fork Lewis population is largely uninfluenced by hatchery effects.

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[99] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[100] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of both populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats.

#### *7.6.1.6 Predation Limiting Factors*

Direct mortality from predation is a secondary limiting factor for all Cascade Chinook salmon populations, including late-fall Chinook salmon. Anthropogenic changes to the structure of habitat have increased predator abundance and effectiveness and led to increased predation by Caspian terns, double-crested cormorants, and various other seabird species in the Columbia River mainstem, estuary, and plume.

### 7.6.2 Late-Fall Chinook Salmon Baseline Threat Impacts and Threat Reduction Targets

Table 7-10 shows the estimated impact on each Lower Columbia River late-fall Chinook salmon population resulting from potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing mortality levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. Cumulative values (both baseline and target) are multiplicative rather than additive. The table also shows the percentage improvement in productivity and abundance (i.e., improvement in population survival) that is needed to achieve the target impacts and corresponding population status.[101]

As an example, the baseline status of the Sandy late-fall Chinook salmon population has been reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 90.8 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 9.2 percent of the historical potential with no human impact. Tributary and estuary habitat, harvest, and hatchery impacts each accounted for reductions in population productivity of 20 percent or more,

[101] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: $[(1-\text{Cumulative}_{\text{Target}})-(1-\text{Cumulative}_{\text{Baseline}})]/[1-\text{Cumulative}_{\text{Baseline}}] \times 100$. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

with corresponding reductions in abundance, spatial structure, and diversity. The Oregon management unit plan identifies a recovery strategy involving significant reductions in the impact of several threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 23 percent to 17 percent (i.e., an approximately 8 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 90.8 percent at baseline to 61.6 percent at the target status. This change would translate into a 310 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for the Washington population reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for the Oregon population reflect conditions through 2004. Dam impacts for the Washington population reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for the Oregon population, the estimate of impacts in the "Dams" column of the Table 7-10 reflects direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for the Washington population were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); for the Oregon population, recovery planners used hatchery impact rates equivalent to one-half the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting concern about genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 7-10 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 7-10 for the Oregon and Washington populations are not necessarily directly comparable. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 7-10 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 7-10 reflect policy decisions and the methodologies and assumptions used by the different recovery

planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of Chinook salmon exposed to that particular category of threats, whether or not they are exposed to threats in other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[102] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

Both the North Fork Lewis and Sandy populations are currently considered viable; however, the recovery scenario calls for the persistence probability of the Sandy population to be raised from high to very high. This will be accomplished primarily through reductions in harvest and hatchery impacts. As with spring and fall Chinook salmon, recent actions have substantially reduced harvest impacts on late-fall Chinook salmon over baseline conditions, but additional reductions in harvest impacts are called for to achieve the target status for the Sandy population. More modest reductions in the tributary and estuarine habitat, hydropower, and predation threat categories are expected to support the gains achieved through reductions in harvest and hatchery impacts.

[102] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

**Table 7-10**

*Impacts of Potentially Manageable Threats and Impact Reduction Targets Consistent with Recovery of LCR Late-fall Chinook Salmon Populations*

| Population | Impacts at Baseline[103] | | | | | | | Impacts at Target | | | | | | | % Survival Improvement Needed[111] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[104] | Est[105] | Dams[106] | Harv[107] | Hat[108] | Pred[109] | Cumulative[110] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumulative | |
| **Cascade Late Fall** | | | | | | | | | | | | | | | |
| NF Lewis (WA) | 0.10 | 0.23 | 0.16 | 0.50 | 0.05 | 0.11 | 0.7539 | 0.10 | 0.23 | 0.16 | 0.50 | 0.05 | 0.11 | 0.7539 | 0 |
| Sandy (OR) | 0.23 | 0.31 | 0.03 | 0.50 | 0.25 | 0.07 | 0.9074 | 0.17 | 0.26 | 0.00 | 0.30 | 0.05 | 0.06 | 0.6161 | 310 |

[103] Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

[104] Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

[105] Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

[106] Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

[107] Includes direct and indirect mortality.

[108] Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

[109] Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

[110] Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$. Minor differences from numbers in ODFW 2010 are due to rounding.

[111] Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target), using the following equation: $[(1-\text{Cumulative}_{\text{Target}})-(1-\text{Cumulative}_{\text{Baseline}})]/[1-\text{Cumulative}_{\text{Baseline}}] \times 100$. These cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

## 7.6.3 Late-Fall Chinook Salmon Recovery Strategy

### *7.6.3.1 Strategy Summary*

The recovery strategy for the late-fall component of the Lower Columbia River Chinook salmon ESU is designed to maintain the two healthy populations (North Fork Lewis and Sandy) and raise the persistence probability of the Sandy population from high to very high. Key elements of the strategy are as follows:

1. Implement the regional hatchery strategy. Minimize the impacts of hatchery releases of steelhead, coho, and spring Chinook salmon on late-fall Chinook salmon. Continue the current practice of not releasing hatchery fall Chinook salmon into the North Fork Lewis River.

2. Reduce harvest impacts on the Sandy late-fall population by using the same harvest strategies identified for tule fall Chinook salmon. Continue to manage fisheries to meet the spawning escapement goal for the Lewis River late-fall population and consider reassessing the goal as new data are acquired.

3. Implement actions in the regional tributary and estuary habitat strategy designed to benefit tule fall Chinook salmon. Implement the stratum-level tributary habitat strategies designated for tule fall Chinook.

Improving the persistence of the Sandy population will be accomplished primarily through reductions in harvest and hatchery impacts. As with spring and tule fall Chinook salmon, recent actions have substantially reduced harvest impacts on late-fall Chinook salmon over baseline conditions, but additional reductions in harvest impacts are called for to achieve the target status for the Sandy population.

### *7.6.3.2 Late-Fall Chinook Salmon Tributary and Estuarine Habitat Strategy*

In general, tributary and estuary habitat actions designed to benefit tule fall Chinook salmon will benefit the two late-fall Chinook salmon populations. Actions include those in the regional tributary and estuary habitat strategies (see Sections 4.1.2 and 4.2.2) and the stratum-level tributary habitat strategies described in Section 7.5.3.2.

### *7.6.3.3 Late-Fall Chinook Salmon Hydropower Strategy*

Tributary hydropower impacts, which had baseline effects on the Sandy late-fall population, have been addressed by the removal of PGE's Marmot and Little Sandy dams (ODFW 2010). The hydropower strategy also includes implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. (See the regional hydropower strategy in Section 4.3.2).

#### *7.6.3.4 Late-Fall Chinook Salmon Harvest Strategy*

Late-fall Chinook salmon are captured in many of the same ocean fisheries as their early fall run counterparts, although overall, inshore recreational and net harvest impacts are somewhat less for late-run fall Chinook salmon. Fisheries are managed to meet a spawning escapement goal for Lower Columbia River bright fall Chinook salmon that is based on the North Fork Lewis river population. In recent years, this escapement goal has been 5,700 natural adult late-fall Chinook salmon. Under the recovery strategy, ocean and freshwater fisheries would continue to employ escapement goal management for Lewis River late-fall Chinook salmon. The escapement goal may be reassessed as new data are acquired (LCFRB 2010a). Consistent with the regional harvest strategy (see Section 4.5.2), the Oregon management unit plan targets a reduction in harvest impacts for the Sandy late-fall Chinook salmon population from 50 percent to 30 percent and expects that this reduction would be achieved through the same harvest strategies identified for tule fall Chinook salmon.

#### *7.6.3.5 Late-Fall Chinook Salmon Hatchery Strategy*

The regional hatchery strategy described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River late-fall Chinook salmon. Lewis River naturally spawning late-fall Chinook salmon are the healthiest Chinook salmon population in the lower Columbia Basin and have been largely uninfluenced by hatchery production. Hatchery late-fall Chinook salmon are not released into the North Lewis River and releases should not be considered in the future. Hatchery releases of steelhead, coho, and spring Chinook salmon, either from the hatchery harvest program or from the upper Lewis natural reintroduction program, must include strategies to minimize impacts to rearing naturally produced fall and late-fall Chinook salmon. Hatchery strays have had a lesser, though still key, effect on the Sandy late-fall Chinook salmon population, with stray rates at one time averaging 24 percent but currently assumed to be less than 10 percent (lower than the hatchery threat reduction target for the Sandy late-fall population) (ODFW 2010).

#### *7.6.3.6 Late-Fall Chinook Salmon Predation Strategy*

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia River ESUs, including late-fall Chinook salmon.

#### *7.6.3.7 Critical Uncertainties*

For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). In addition, the following are critical uncertainties specific to the Lower Columbia River late-fall Chinook salmon recovery strategy:

- Evaluate assumptions about harvest: are impacts on the Sandy late fall Chinook salmon population lower than those on the tules because of run timing differences?

- Adequacy of the spatial distribution of the North Fork Lewis population to maintain the population at a high probability of persistence

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a 2010 workshop. They are preliminary priorities only; as described in Chapter 10, additional discussion among recovery planners and NMFS staff will be needed to finalize future research and monitoring priorities for Lower Columbia River Chinook salmon.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The Washington management unit plan has a discrete section on critical uncertainties for all of the ESUs in general (see Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the Lower Columbia Fish Recovery Board completed its *Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above also does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which Chapter 10 discusses in depth. RME and adaptive management will be key components of the Lower Columbia River late-fall Chinook salmon recovery strategy.

## 7.7 Delisting Criteria Conclusion for LCR Chinook Salmon

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Lower Columbia River Chinook salmon ESU from the Federal List of Endangered and Threatened Wildlife and Plants (that is, to delist the ESU or DPS), NMFS must determine that the ESU, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12). The recovery criteria in this plan (both biological and threats criteria) meet this statutory requirement.

As described in Section 7.3, if the scenario in Table 7-4 were achieved, it would exceed the WLC TRT's stratum-level viability criteria in the Coast and Cascade fall strata, the

Cascade spring stratum, and the Cascade late-fall stratum. However, the scenario for the Gorge fall and Gorge spring strata does not meet WLC TRT criteria because, within each stratum, the scenario targets only one population (the Hood) for high persistence probability, instead of two (see Table 7-11).[112] Exceeding the WLC TRT criteria in the Cascade fall and spring Chinook strata was intentional on the part of local recovery planners to compensate for uncertainties about meeting the WLC TRT's criteria in the Gorge fall and spring strata. In addition, multiple spring Chinook salmon populations are prioritized for aggressive recovery efforts to balance risks associated with the uncertainty of success in reintroducing spring Chinook salmon populations above tributary dams in the Cowlitz and Lewis systems.

**Table 7-11**
*LCR Chinook Salmon Recovery Scenario Scores Relative to WLC TRT Viability Criteria*

| Species | Number of Primary Populations | | | | | Stratum Average Criteria | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Coast | Cascade | Gorge | Total | | Coast | Cascade | Gorge |
| Fall Chinook | n ≥ high | 4 | 4 | 1 | 9 | Avg. score | 2.36 | 2.35 | 2.25* |
| | TRT criterion (n ≥ 2) met? | Yes | Yes | No | | TRT criterion (avg. ≥ 2.25) met? | Yes | Yes | * |
| Late-Fall Chinook | n ≥ high | -- | 2 | -- | 2 | Avg. score | -- | 4.00 | -- |
| | TRT criterion (n ≥ 2) met? | -- | Yes | -- | | TRT criterion (avg. ≥ 2.25) met? | -- | Yes | -- |
| Spring Chinook | n ≥ high | -- | 4 | 1 | 5 | Avg. score | -- | 2.36 | 2.75* |
| | TRT criterion (n ≥ 2) met? | -- | Yes | No | | TRT criterion (avg. ≥ 2.25) met? | -- | Yes | * |

*Stratum does not meet WLC TRT criterion for number of populations at high or higher probability of persistence.

Source: Based on LCFRB 2010a, Table 4-7

Recovery planners' uncertainty about meeting WLC TRT criteria in the Gorge fall and spring Chinook salmon strata is based on questions about available habitat and anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of habitat by Bonneville Reservoir) and on questions regarding Gorge strata and population delineations and historical role (LCFRB 2010a, ODFW 2010). These questions include whether the Gorge populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the

[112] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher.

Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum.

As discussed in Section 3.2, NMFS has considered the WLC TRT's viability criteria (from McElhany et al. 2003 and 2006 and summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios and population-level abundance and productivity goals developed by the management unit planners, and the questions management unit planners raised regarding the historical role of the Gorge strata.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of an ESU that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the recovery scenario in the management unit plans for Lower Columbia River Chinook salmon (summarized in Table 3-1 of this recovery plan) and the associated population-level abundance and productivity goals (see Section 7.3).

Regarding the divergence of the scenario from the WLC TRT's criteria, the TRT noted in its revised viability criteria (McElhany et al. 2006) the need for case-by-case evaluations of the continuum of ESU-level risk associated with some strata not meeting their criteria. In commenting on the recovery scenarios presented in the interim Washington management unit plan[113]—and by extension the recovery scenarios presented in Table 3-1 of this plan—the WLC TRT stated that achieving the recovery scenarios would improve the status of the Gorge strata, even if the TRT's criteria for those strata were not met. The TRT also noted that targeting the Cascade strata for very high persistence (above the minimum TRT criteria) would help lower ESU extinction risk. In addition, the TRT noted that the Gorge and Cascade strata are relatively similar compared to the Cascade and Coast strata. Also significant in the TRT's view was that options for recovery of the Gorge stratum would be preserved, in case future conditions or analyses were to require high stratum persistence for ESU viability (McElhany et al. 2006, p. 9).

Based on the information provided by the WLC TRT and the management unit recovery planners, NMFS concludes that the recovery scenarios in Table 3-1 and the associated population-level abundance and productivity goals in Section 7.3 represent one of multiple possible scenarios that would meet biological criteria for delisting. The similarities between the Gorge and Cascade strata, coupled with compensation in the Cascade stratum for not meeting TRT criteria in the Gorge stratum, would provide an ESU no longer likely to become endangered. NMFS endorses the recovery scenario and population-level goals found in the management unit plans for Lower Columbia River Chinook salmon (summarized in Table 3-1 and Section 7.3) as one of multiple possible scenarios consistent with delisting.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and stratum merits further examination. The extent to which

[113] In February 2006, NMFS approved the December 2004 version of the Washington management unit plan as an interim regional recovery plan for Lower Columbia River Chinook salmon and steelhead and Columbia River chum salmon. In May 2010, the LCFRB completed a revision of its 2004 plan (LCFRB 2010a), which is incorporated into this ESU-level recovery plan as Appendix B.

compensation in the Cascade stratum is ultimately considered necessary to achieve an acceptably low risk at the ESU level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following delisting criteria for the Lower Columbia River Chinook salmon ESU (NMFS has amended the WLC TRT's criteria to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge strata):

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition. High probability of stratum persistence is defined as:

    a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

    b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

    c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

    A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria described in Section 3.2.2 have been met.

# 8. Columbia River Chum Salmon

## 8.1 Chum Salmon Biological Background

### 8.1.1 Chum Salmon Life History and Habitat

Columbia River chum salmon (*Oncorhynchus keta*) once were widely distributed throughout the lower Columbia Basin and spawned in the mainstem Columbia and the lower reaches of most lower Columbia River tributaries. Historically, spawning occurred as far upstream as the Umatilla and Walla Walla rivers, but it now is restricted largely to tributary and mainstem areas downstream of Bonneville Dam (LCFRB 2010a, NMFS 2013). Although chum salmon are strong swimmers, they rarely pass river blockages and waterfalls that pose no hindrance to other salmon or steelhead (ODFW 2010); thus, they spawn in low-gradient, low-elevation reaches and side channels (LCFRB 2010a). Chum salmon enter fresh water close to the time of spawning. They need clean gravel for spawning, and spawning sites typically are associated with areas of upwelling water. For example, in 1999 chum salmon were discovered spawning along the Washington shoreline near the I-205 Glen Jackson Bridge, where upwelling occurs. In addition, a significant proportion of chum salmon returning to Hamilton Creek spawn in a spring-fed channel, and portions of the Grays River and Hardy Creek populations spawn in the area of springs (LCFRB 2010a).

Adult chum salmon returning to the Columbia River at the present time are virtually all fall-run fish, entering fresh water from mid-October through November and spawning from early November to late December (see Figure 8-1) (LCFRB 2010a). There is also evidence that a summer-run chum salmon population returned historically to the Cowlitz River, and fish displaying this life history are occasionally observed there (Ford 2011, Myers et al. 2006).

Various physical and biotic factors affect the time it takes for eggs to incubate, hatch, and emerge as alevins from the gravel, but water temperature is believed to have the most influence on embryonic development; lower water temperatures can prolong the time required from fertilization to hatching by 1.5 to 4.5 months (NMFS 2013). Chum salmon fry emerge from March through May (LCFRB 2010a), typically at night (ODFW 2010), and are believed to migrate promptly downstream to the estuary for rearing. Chum salmon fry are capable of adapting to seawater soon after emergence from gravel (LCFRB 2010a). Their small size at emigration is thought to make chum salmon susceptible to predation mortality during at this life stage (LCFRB 2010a).

Given the minimal time chum salmon spend in their natal streams, the period of estuarine residency appears to be a critical phase in their life history and may play a major role in determining the size of returning adults (NMFS 2013). Chum and ocean-type Chinook salmon usually spend more time in estuaries than do other anadromous salmonids (Dorcey et al. 1978 and Healey et al. 1982, as cited in NMFS 2013)—weeks or months, rather than days or weeks (NMFS 2011a). Shallow, protected habitats such as salt marshes, tidal creeks, and intertidal flats serve as significant rearing areas for juvenile chum salmon during estuarine residency (LCFRB 2010a).

Juvenile chum salmon rear in the Columbia River estuary from February through June before beginning long-distance ocean migrations (LCFRB 2010a). Chum salmon remain in the North Pacific and Bering Sea for 2 to 6 years, with most adults returning to the Columbia River as 4-year-olds (ODFW 2010). All chum salmon die after spawning.

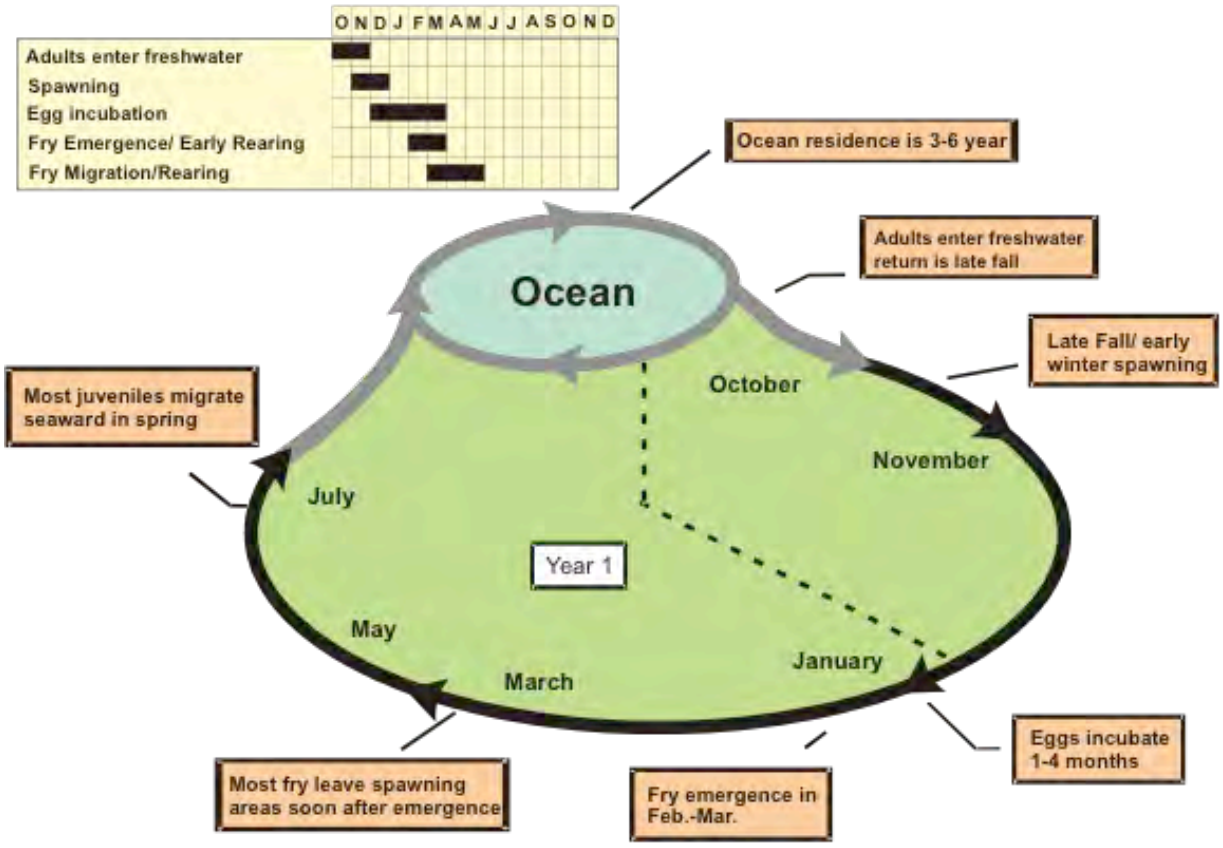


**Figure 8-1.** *Life Cycle of Columbia River Chum Salmon*

(Source: LCFRB 2010a)

### 8.1.2 Historical Distribution and Population Structure of Columbia River Chum Salmon

The Columbia River chum salmon ESU historically consisted of 17 independent populations. Of these, 16 were fall-run populations and one was a summer-run population that returned to the Cowlitz River.[1] Table 8-1 lists these populations and

[1] Recent genetic studies indicate the historical existence of a summer-run chum population in the Cowlitz subbasin (Ford 2011). Based on earlier information about the possible existence of this population (see Myers et al. 2006), the Washington management unit plan recognized the need to protect and restore the full range of diversity in this ESU, and incorporated actions to recover summer-run chum in the Cowlitz subbasin to a medium probability of persistence. The WLC TRT defines a stratum as a group of populations sharing major life history characteristics (e.g., run timing) and ecological zones and representing a major diversity component within an ESU (McElhany et al. 2003). It remains unclear whether summer-run chum salmon in the Cowlitz River represent a separate stratum from Cascade fall-run chum or the early

indicates core populations (which historically were highly productive) and genetic legacy populations (which represent important historical genetic diversity). Figure 8-2 shows the geographical distribution of Columbia River chum salmon strata and populations.

The Columbia River chum salmon ESU includes fish from three artificial propagation programs in Washington: the Chinook River (Sea Resources Hatchery), Grays River, and Washougal River/Duncan Creek chum salmon hatchery programs (70 *Federal Register* 37176). These programs produce fry for efforts to supplement natural populations (LCFRB 2010a). In 2010, the Oregon Department of Fish and Wildlife initiated a new chum salmon hatchery program, which NMFS has not yet evaluated for inclusion in the ESU, at Big Creek Hatchery to develop chum salmon for reintroduction into lower Columbia River tributaries in Oregon (76 *Federal Register* 50448, Jones 2011).

**Table 8-1**
*Historical Columbia River Chum Salmon Populations*

| Stratum | Historical Populations | Core or Genetic Legacy Populations |
|---|---|---|
| Coast | Youngs Bay (OR) | Core |
| | Grays/Chinook (WA) | Core, genetic legacy |
| | Big Creek (OR) | Core |
| | Elochoman/Skamakowa (WA) | Core |
| | Clatskanie (OR) | |
| | Mill/Abernathy/Germany (WA) | |
| | Scappoose (OR) | |
| Cascade | Cowlitz - fall (WA) | Core |
| | Cowlitz - summer (WA) | Core |
| | Kalama (WA) | |
| | Lewis (WA) | Core |
| | Salmon Creek (WA) | |
| | Clackamas (OR) | Core |
| | Sandy (OR) | |
| | Washougal (WA) | |
| Gorge | Lower Gorge (WA & OR) | Core, genetic legacy |
| | Upper Gorge[2] (WA & OR) | |

Source: Myers et al. (2006), McElhany et al. (2003).

component of broadly distributed run timing. In its 2011 5-year review, the NMFS Northwest Fisheries Science Center concluded that available information suggests adding the summer-run chum population to the Cascade stratum of the Columbia River chum ESU (Ford 2011). This approach is consistent with the Washington management unit plan's approach. Organizationally within this ESU-level recovery plan, Cowlitz summer chum are included in the Cascade chum stratum.

[2] Includes White Salmon population.

## 8.2 Baseline Population Status of Columbia River Chum Salmon

Over the last century, Columbia River chum salmon returns have collapsed from hundreds of thousands to just a few thousand per year. Of the 17 populations that historically made up this ESU, 15 of them (six in Oregon and nine in Washington) are so depleted that either their baseline probability of persistence is very low or they are extirpated or nearly so (LCFRB 2010a, ODFW 2010, Ford 2011).[3] All three strata in the ESU fall significantly short of the WLC TRT criteria for viability.

Currently almost all natural production occurs in just two populations: the Grays/Chinook and the Lower Gorge (see Figure 8-2).The Grays/Chinook population has a moderate persistence probability, and the Lower Gorge population has a high probability of persistence (LCFRB 2010a). The Lower Gorge population meets abundance and productivity criteria for very high levels of viability, but the distribution of spawning habitat (i.e., spatial structure) for the population has been significantly reduced (LCFRB 2010a); spatial structure may need to be improved, at least in part, through better performance from the Oregon portion of the population.

The very low persistence probabilities or possible extirpations of most chum salmon populations are due to low abundance, productivity, spatial structure, and diversity. Habitat loss has severely reduced the distribution of suitable chum salmon habitats, with accompanying reductions in abundance and productivity. Limited distribution also increases risk to the ESU from local disturbances. Although hatchery production of chum salmon has been limited and hatchery effects on diversity are thought to have been relatively small,[4] diversity has been greatly reduced at the ESU level because of presumed extirpations and the low abundance in the remaining populations (fewer than 100 spawners per year for most populations) (LCFRB 2010a). For additional discussion of Columbia River chum salmon population status, see the management unit plans (LCFRB 2010a, pp. 6-33 through 6-35; ODFW 2010, pp. 57-58; and NMFS 2013, p. 4-3) and Ford (2011).

[3] As described in Section 2.5 and 2.6, the WLC TRT recommended methods for evaluating the status of Lower Columbia River salmon and steelhead populations. The TRT's approach is based on evaluating the population parameters of abundance, productivity, spatial structure, and diversity and then integrating those assessments into an overall assessment of population persistence probability. As also described in Section 5.1, management unit recovery planners evaluated their respective populations' baseline status in a manner generally consistent with the WLC TRT's approach, with the baseline period being either circa 1999 (for Washington populations) or 2006-2008 (for Oregon populations). Unless otherwise noted, NMFS and the management unit planners believe that those assessments accurately the status of the population at that time; the assessments are the basis for the summaries presented here and are consistent with the conclusions of the Northwest Fisheries Science Center in its *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act* (Ford 2011). New information on population status will continue to accumulate over time and will be taken into account as needed to reflect the best available science regarding a population's status.

[4] LCFRB 2010a reports that the proportion of hatchery-origin spawners for most Washington populations is 3 percent or less. The exception is the Grays/Chinook population, which has a pHOS of 54 percent (LCFRB 2010a) because a conservation hatchery program is being used to supplement natural production in that population.

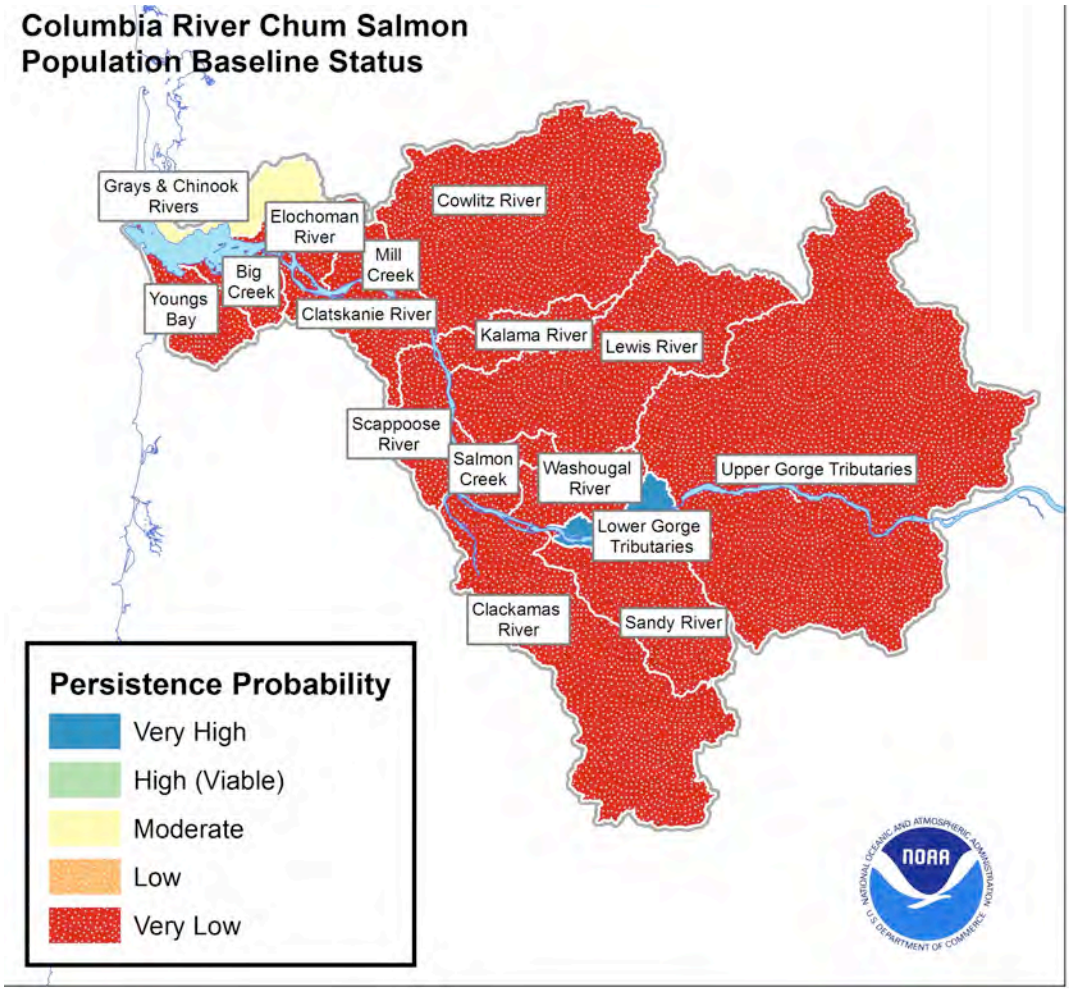


**Figure 8-2.** *Baseline Status of Historical Columbia River Chum Salmon Populations*

## 8.3 Target Status and Conservation Gaps for Chum Salmon Populations

Table 8-2 shows the baseline and target status and historical and target abundance for Washington Columbia River chum salmon population, along with target status and abundance for Oregon populations.[5] Local recovery planners coordinated with NMFS in making decisions about the target status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities. Oregon did not identify abundance targets for chum salmon populations because quantitative data for use in calculating abundance targets and conservation gaps are not available. In Table 8-2, NMFS has included placeholder abundance targets for Oregon chum salmon populations based on the minimum

[5] Because quantitative data on the status of Oregon chum populations are lacking, ODFW (2010) variously refers to these populations as extirpated, nearly extirpated, functionally extirpated, or extremely depressed. It is often difficult to distinguish between a population that is truly extirpated and one that is not entirely extirpated but is at significant short-term risk. This ESU-level plan refers to Oregon chum salmon populations as very high risk or extirpated or nearly so.

abundance thresholds presented in McElhany et al. 2006 and 2007. The minimum abundance threshold (MAT) represents a lower bound estimate for average population size associated with a given persistence level. Minimum abundance thresholds take into account environmental variation, genetic issues, ecosystem functions, catastrophic risk, and other biological and ecological factors that affect the relationship between abundance and persistence probability and that may not be explicitly addressed in the viability curve analysis. McElhany et al. (2007) advised that, before a population is assigned to a particular risk category, the population should exceed the viability curve criterion, minimal abundance threshold, and any qualitative TRT criteria.[6] (Note: the target statuses in Table 8-2 are the same as the persistence probabilities in the recovery scenario presented in Table 3-1 in Section 3.1.3.)

Very large improvements are needed in the persistence probability of almost all chum salmon populations if the ESU is to achieve recovery (see Figure 8-3): nine of the eleven historical populations in Washington have very low baseline persistence probabilities, as do all six historical Oregon populations; it is possible that some populations are extirpated. Of the 17 historical populations, nine are targeted for high or better persistence probability. Some level of recovery effort will be needed for every population to arrest or reverse continuing long-tem declining trends; this is true for stabilizing populations, which are expected to remain at their baseline status, and for the ESU's two best-performing populations—the Grays/Chinook and Lower Gorge—which have baseline persistence probabilities of medium and high, respectively. For these latter two populations, meeting recovery objectives will require significant improvement in spatial structure. The Grays/Chinook will need improvements in diversity as well.

In the Coast stratum, five of seven populations are targeted for high or very high persistence probability. These include the Grays/Chinook and Elochoman/Skamakowa, which historically were among the most productive populations in the stratum. (The Grays/Chinook also is one of only two genetic legacy populations in the ESU.) However, two other Coast stratum populations that also historically were highly productive—Youngs Bay and Big Creek—are expected to remain at their baseline status of very low persistence probability to allow for incidental harvest of chum salmon that may occur in terminal fisheries that target hatchery coho and Chinook (ODFW 2010).

Of eight populations in the Cascade stratum, three—the Lewis, Sandy, and Washougal—are targeted for high or high-plus persistence probability; in the case of the Lewis, this is in part because it is a core population, meaning that historically it was one of the most productive in the stratum. Chum salmon in the Cowlitz and the Clackamas subbasins also are core populations.[7] However, extensive diking in the Longview/Kelso area limits the recovery prospects for chum salmon in the Cowlitz subbasin, and the Oregon chum recovery strategy does not require both the Clackamas and Sandy

[6] Minimum abundance thresholds are also specific to historical population size. Estimates of historical watershed size available to chum salmon populations are not available at this time, so the minimum abundance thresholds in Table 8-2 reflect the upper end of the range of the minimum abundance threshold for the small size category of chum salmon populations.

[7] The WLC TRT also indicated that the Cowlitz, including fall and summer-run fish, was likely an important component of the genetic legacy of the ESU (McElhany et al. 2003). As discussed above, preserving the summer component of the Columbia River chum ESU is an important recovery objective.

populations to be viable.[8] Thus the target status for the Cowlitz and Clackamas populations is medium. The Salmon Creek population is expected to remain at its baseline persistence probability of very low because of severe habitat degradation in that subbasin and the historically small size of the population.

In the Gorge stratum, which contains two populations, the Lower Gorge population (a core and genetic legacy population) is targeted for high persistence probability, and the Upper Gorge population is targeted for medium probability of persistence. The management unit recovery planners did not consider it feasible to achieve a higher persistence probability for the latter population. Challenges include the small amount of historical and current habitat (and thus the limited options for restoration); anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of historical spawning habitat by Bonneville Reservoir and roads that restrict access to habitat); high uncertainty in the data and analyses for small populations[9]; and the possibly inaccurate designation of population structure for this stratum. The Oregon management unit plan states that most of these issues are related to the population structure designation and suggests re-evaluating the Gorge stratum population structure for all species (ODFW 2010). As discussed in Section 3.2.1, NMFS agrees that such an evaluation is needed.

If the scenario in Table 8-2 were achieved, it would slightly exceed the WLC TRT's stratum-level viability criteria in the Coast and Cascade strata. However, the scenario would not meet criteria in the Gorge stratum because only one Gorge population (the Lower Gorge) would be viable, instead of two. Exceeding the criteria in the Coast and Cascade strata was intentional on the part of local recovery planners to compensate for high levels of uncertainty about recovery prospects in the Gorge stratum (LCFRB 2010a). (Delisting criteria for the Columbia River chum ESU are described in Section 3.2 and below in Section 8.7.)

Figure 8-3 displays the population-level conservation gaps for Columbia River chum salmon graphically. The conservation gap reflects the magnitude of improvement needed to move a population from its baseline status to the target status. For additional discussion of the status targets and conservation gaps for Columbia River chum salmon populations, see the management unit plans (LCFRB 2010a, pp. 6-33 through 6-37, ODFW 2010 pp. 148-150, and NMFS 2013 p. 3-12).

[8] Oregon recovery planners set the desired status for chum salmon populations based on having half of the Oregon populations in a stratum reaching low extinction risk and the others improving significantly.
[9] In the method used by the WLC TRT and management unit planners to establish abundance goals, target abundance is based to some extent on the gap between current and historical abundance. If the historical abundance of Gorge chum salmon populations has been significantly overestimated, then the abundance needed to achieve their target status may also be overestimated (ODFW 2010).

## Table 8-2

*Baseline and Target Persistence Probability and Abundance of Columbia River Chum Salmon Populations*

| | | | Baseline Persistence Probability[10] | | | | | Abundance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stratum** | **Population** | **Contribution** | **A&P** | **S** | **D** | **Net[11]** | **Target Persistence Probability** | **Historical** | **Baseline[12]** | **Target[13]** |
| Coast | Youngs Bay (OR) [C] | Stabilizing | --[14] | -- | -- | VL | VL | -- | -- | <500 |
| | Grays/Chinook (WA) [C, GL] | Primary | VH | M | H | M | VH | 10,000 | 1,600 | 1,600 |
| | Big Creek (OR) [C] | Stabilizing | -- | -- | -- | VL | VL | -- | -- | <500 |
| | Elochoman/Skamakowa (WA) [C] | Primary | VL | H | L | VL | H | 16,000 | < 200 | 1,300 |
| | Clatskanie (OR) | Primary | -- | -- | -- | VL | H | -- | -- | 1,000 |
| | Mill/Abernathy/Germany (WA) | Primary | VL | H | L | VL | H | 7,000 | < 100 | 1,300 |
| | Scappoose (OR) | Primary | -- | -- | -- | VL | H | -- | -- | 1,000 |
| Cascade | Cowlitz - fall (WA) [C] | Contributing | VL | H | L | VL | M | 195,000 | < 300 | 900 |
| | Cowlitz - Summer (WA) [C] | Contributing | VL | L | L | VL | M | -- | -- | 900 |
| | Kalama (WA) | Contributing | VL | H | L | VL | M | 20,000 | < 100 | 900 |

[10] A&P = Abundance and productivity, S = spatial structure, and D = genetic and life history diversity. Net = overall persistence probability of the population. VL = very low, L = low, M = moderate, H = high, VH = very high.

[11] All Oregon populations are considered to have a very low baseline persistence probability.

[12] Baseline abundance was estimated as described in Section 5.1 and does not equal observed natural-origin spawner counts. The baseline is a modeled abundance that represents 100-year forward projections under conditions representative of a recent baseline period using a population viability analysis that is functionally equivalent to the risk analyses in McElhany et al. (2007). Washington numbers reflect fishery impacts prevalent in the period immediately prior to listing in 1999.

[13] Oregon did not identify abundance targets for chum salmon populations because quantitative data for use in calculating abundance targets and conservation gaps are not available. In this table, NMFS has included placeholder abundance targets for Oregon chum salmon populations based on the minimum abundance thresholds presented in McElhany et al. 2006 and 2007. The minimum abundance threshold (MAT) represents a lower bound estimate for average population size associated with a given persistence level. Minimum abundance thresholds take into account environmental variation, genetic issues, ecosystem functions, catastrophic risk, and other biological and ecological factors that affect the relationship between abundance and persistence probability and that may not be explicitly addressed in the viability curve analysis. McElhany et al. (2007) advised that, before a population is assigned to a particular risk category, the population should exceed the viability curve criterion, minimal abundance threshold, and any qualitative TRT criteria.

[14] "—" indicates that no data are available from which to make a quantitative assessment.

## Table 8-2

*Baseline and Target Persistence Probability and Abundance of Columbia River Chum Salmon Populations*

| | | | Baseline Persistence Probability[10] | | | | | Abundance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stratum** | **Population** | **Contribution** | **A&P** | **S** | **D** | **Net[11]** | **Target Persistence Probability** | **Historical** | **Baseline[12]** | **Target[13]** |
| | Lewis (WA) [C] | Primary | VL | H | L | VL | H | 125,000 | < 100 | 1,300 |
| | Salmon Creek (WA) | Stabilizing | VL | L | L | VL | VL | -- | < 100 | -- |
| | Clackamas (OR) [C] | Contributing | -- | -- | -- | VL | M | -- | -- | 500 |
| | Sandy (OR) | Primary | -- | -- | -- | VL | H | -- | -- | 1,000 |
| | Washougal (WA) | Primary | VL | H | L | VL | H+ | 18,000 | < 100 | 1,300 |
| Gorge | Lower Gorge (WA & OR) [C, GL] | Primary | VH | H | VH | H | VH | 6,000 | 2,000 | 2,000 |
| | Upper Gorge (WA & OR) | Contributing | VL | L | L | VL | M | 11,000 | < 50 | 900 |

C = Core populations, meaning those that historically were the most productive.

G = Genetic legacy populations, which best represent historical genetic diversity.

Source: LCFRB (2010a) and ODFW (2010).

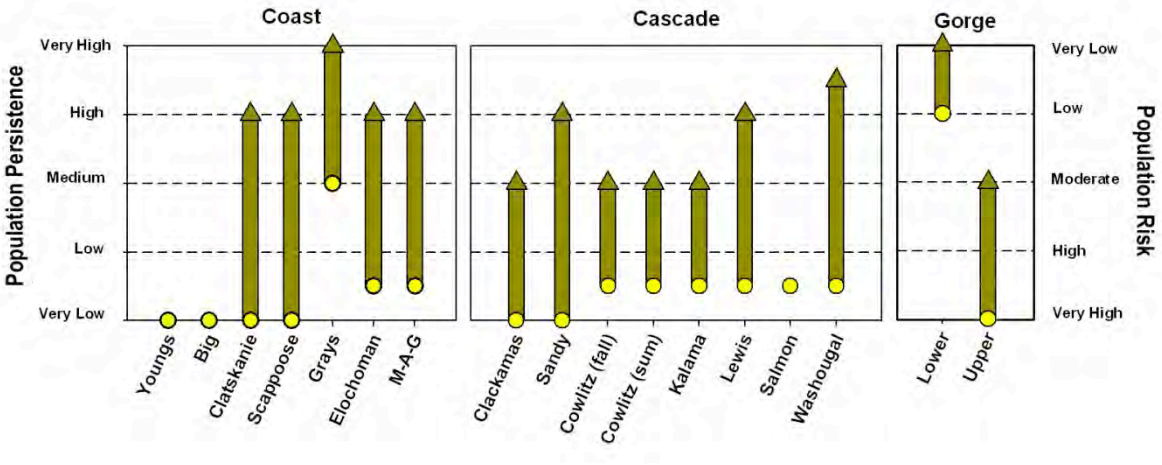


**Figure 8-3.** *Conservation Gaps for Columbia River Chum Salmon Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

## 8.4 Limiting Factors and Threats for Columbia River Chum Salmon

Columbia River chum salmon have been—and continue to be—affected by loss and degradation of spawning and rearing habitat, the impacts of mainstem hydropower dams on upstream access and downstream habitats, and the legacy effects of historical harvest; together, these factors have reduced the persistence probability of all populations. Under baseline conditions, constrained spatial structure at the ESU level (related to conversion, degradation, and inundation of habitat) contributes to very low abundance and low genetic diversity in most populations and increases risk to the ESU from local disturbances.

Table 8-3 and the text that follows summarize baseline limiting factors and threats for Columbia River chum salmon strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and indentifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4). In addition, in Table 8-3 NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[15] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations. Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting each Columbia River chum salmon population, including magnitude, spatial scale, and relative impact (see LCFRB 2010a, Chapter 3 and various sections of Volume II; ODFW 2010, pp. 141-146; and NMFS 2013, Chapter 5). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 8.5 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

[15] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

**Table 8-3**

*Baseline Limiting Factors and Threats Affecting Columbia River Chum Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast | Cascade | Gorge |
|---|---|---|---|---|---|
| **Tributary Habitat Limiting Factors**[16] | | | | | |
| Riparian Condition | Past and/or current land use practices | All | Primary for WA juveniles | Primary for WA juveniles | Primary for Lower and Upper Gorge adults and juveniles |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Primary for WA juveniles | Primary for WA juveniles | Primary for Lower and Upper Gorge adults and juveniles |
| Peripheral and Transitional Habitats: Side Channel and Wetland Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for WA juveniles | Primary for WA juveniles | Primary for Lower and Upper Gorge adults and juveniles |
| Peripheral and Transitional Habitats: Floodplain Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for WA juveniles | Primary for WA juveniles | Primary for Lower and Upper Gorge adults and juveniles |
| Sediment Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for WA juveniles; secondary for OR juveniles | Primary for Cowlitz, Kalama, and Washougal juveniles; secondary for OR juveniles | |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dams | A,P,D | | Primary for Kalama, Lewis, and Salmon Creek juveniles | |
| Water Quantity (Flow) | Dams, land use, and water withdrawals for irrigation, municipal uses, and hatchery operations | All | Secondary for juveniles in all populations | Primary for Cowlitz and Kalama juveniles; secondary for juveniles in all other populations | Secondary for Lower and Upper Gorge juveniles |

[16] Tributary habitat limiting factors in this table primarily reflect those identified in the Washington management unit plan. This is because chum salmon do not migrate far up tributaries and Oregon recovery planners categorized chum salmon limiting factors occurring in areas of tidal influence in the lower reaches of tributaries as estuarine. Thus, the relative paucity of tributary habitat limiting factors for Oregon chum salmon populations is an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in the extent of tributary habitat limiting factors or their effects on chum salmon populations.

**Table 8-3**

*Baseline Limiting Factors and Threats Affecting Columbia River Chum Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast | Cascade | Gorge |
|---|---|---|---|---|---|
| **Estuary Habitat Limiting Factors[17]** | | | | | |
| Toxic Contaminants | Agricultural chemicals, urban and industrial practices | A,P,D | Secondary for juveniles in all populations | | |
| Food[18] (Shift from macrodetrital- to microdetrital-based food web) | Dam reservoirs | All | Secondary for juveniles in all populations | | |
| Peripheral and Transitional Habitats: Estuary Condition | Past and/or current land use practices, transportation corridor, mainstem dams | All | Primary for juveniles in all populations | | |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | | |
| Sediment Conditions | Past and/or current land use practices/transportation corridor, dams | All | Primary for juveniles in all populations | | |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dam reservoirs | A,P,D | Secondary for juveniles in all populations | | |
| Water Quantity (Flow) | Columbia River mainstem dams | All | Primary for juveniles in all populations | | |

[17] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this table and Section 8.4.2 reflect the determinations in the Oregon management unit plan, applied to all Columbia River chum salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[18] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

**Table 8-3**

*Baseline Limiting Factors and Threats Affecting Columbia River Chum Salmon: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Coast | Cascade | Gorge |
|---|---|---|---|---|---|
| **Hydropower Limiting Factors** | | | | | |
| Habitat Quantity (Access) | Bonneville Dam | All | | | Primary for Upper Gorge adults and juveniles |
| Habitat Quantity (Inundation) | Bonneville Dam | All | | | Primary for Upper Gorge adults and juveniles |
| **Hatchery Limiting Factors** | | | | | |
| Food | Smolts from all Columbia Basin hatcheries competing for food and space in the estuary | All | | | |
| Population Diversity | Stray hatchery fish interbreeding with wild fish | A,P,D | Secondary for Grays/Chinook adults | | |
| **Predation Limiting Factors** | | | | | |
| Direct Mortality | Dams | A,P,D | | | Secondary for Upper Gorge juveniles |
| Direct Mortality | Hatchery fish | A,P,D | Secondary for juveniles in all populations[19] | | |

### 8.4.1 Tributary Habitat Limiting Factors

The pervasive loss of critical spawning, incubation, and rearing habitat is a primary limiting factor for chum salmon throughout the Lower Columbia subdomain. Chum salmon typically spawn in upwelling areas of clean gravel beds in mainstem and side-channel portions of low-gradient reaches above tidewater. These habitats have been practically eliminated in most systems through a combination of channel alteration and sedimentation that is attributable largely to past and current land uses; these include historical and current forest management, agriculture, rural residential uses, urban development, and gravel extraction. Low-elevation stream reaches have been directly affected by extensive channelization, diking, wetland conversion, stream clearing, and gravel extraction. Impaired watershed processes continue to limit chum salmon habitat through effects on floodplain and wetland habitat conditions and connectivity, riparian conditions and function, and channel structure.

Impaired side channel and wetland conditions, along with degraded floodplain habitat are identified as primary limiting factors for all Washington populations and the two Gorge populations. Channel structure and form issues and degraded riparian conditions also are considered primary limiting factors for juveniles in all Washington populations and for juveniles and adults in the two Gorge populations. Sediment conditions are

[19] Chum salmon fry from all populations may experience predation to varying degrees by hatchery-origin coho, steelhead, and Chinook smolts, although differences in life history patterns may moderate effects and the significance of these interactions is unknown.

identified as a primary limiting factor for all Washington populations in the Coast stratum and for the Cowlitz, Kalama, and Washougal populations in the Cascade stratum, and they are considered a secondary limiting factor for the Oregon portion of the Coast and Cascade strata.[20] In addition, water quality—specifically, elevated water temperature brought about through land use and hydropower reservoirs—is a primary factor for Kalama, Lewis, and Salmon Creek juveniles. Water quantity issues related to altered hydrology and flow timing have been identified as a primary limiting factor for juveniles in the Cowlitz and Kalama populations and as a secondary limiting factor for juveniles in all other chum populations.

In the Coast stratum, tributary habitat limiting factors are largely the same as those described above for the ESU as a whole and are attributable largely to past and current land uses. Lower reaches are mostly in agricultural and rural residential use and have been extensively modified by bank stabilization, levees, and tide gates. Private and state forest land predominates in the upper reaches of Coast ecozone subbasins. The high density of unimproved rural roads throughout the area leads to an abundance of fine sediment in tributary streams that covers spawning gravel and increases turbidity. In the Youngs Bay and Big Creek subbasins, hatchery weirs are identified as secondary limiting factors because they block access to historically productive spawning and rearing habitat for chum salmon.

In the Cascade stratum, tributary habitat limiting factors are largely the same as those described above for the ESU as a whole, with the addition of road crossings that impede chum salmon passage; this has been identified as a secondary limiting factor in the Clackamas and Sandy subbasins. Land uses that have limited the productivity of tributary habitat in this stratum include forest management and timber harvest, agriculture, rural residential and urban development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development, especially in the Salmon Creek and lower Clackamas subbasins.

In the Gorge stratum, habitat-related limiting factors result from past and current land uses; these include a mix of private, state, and federal forest land in the upper mainstem and headwater reaches of the Gorge subbasins, plus transportation and rural residential land uses, with some urban development, in lower mainstem and tributary reaches. Highway and transportation corridors run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes. The associated habitat degradation is considered a primary limiting factor for the Upper and Lower Gorge chum salmon populations. The Upper Gorge population also is significantly affected by habitat loss caused by inundation from

[20] Tributary habitat limiting factors for chum salmon populations primarily reflect those identified in the Washington management unit plan. This is because chum salmon do not migrate far up tributaries and Oregon recovery planners categorized chum salmon limiting factors occurring in areas of tidal influence in the lower reaches of tributaries as estuarine. Thus, the apparent lack of tributary habitat limiting factors for Oregon populations is an artifact of differences in limiting factor assessment methodologies between the two states and not an actual difference in the extent of tributary habitat limiting factors or their effects on chum salmon populations.

Bonneville Reservoir; it is likely that significant amounts of historical spawning and rearing habitat for this population have been inundated.

### 8.4.2 Estuary Habitat Limiting Factors[21]

Estuary habitat conditions are important for juvenile chum salmon, which leave their natal streams as fry and spend considerable time rearing in the estuary. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, and reduced access to peripheral and transitional habitats such as side channels and wetlands also are identified as primary limiting factors for juveniles from all populations. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor—while juveniles' access to side channels and wetlands is impaired by these same land uses but also by flow alterations caused by mainstem dams.

Secondary limiting factors in the estuary that affect chum salmon are exposure to toxic contaminants (from urban, agricultural, and industrial sources) and elevated late summer and fall water temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs.[22] Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations.[23] These changes in the estuarine food web are caused primarily by

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[21] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the ESU, the estuarine limiting factors in this section and in Table 8-3 reflect the determinations in the Oregon management unit plan, applied to all Columbia River chum salmon populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[22] Although the management unit plans identified temperature impacts as a secondary limiting factor for juveniles in all populations, the timing of juvenile chum salmon migration and rearing raises questions about the significance of this limiting factor; see Section 8.4.3.

[23] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

### 8.4.3 Hydropower Limiting Factors

Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Columbia River chum salmon in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web (see Section 8.4.2).[24] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Although the management unit recovery plans identified temperature impacts of the hydropower system as a secondary limiting factor for all juvenile chum salmon, juvenile chum salmon are rearing in and migrating through the mainstem in February through July, with peak presence in May(Dawley et al. 1986, McCabe et al. 1986, Roegner et al. 2004, Bottom et al. 2008, cited in Figure 2.2 of Carter et al. 2009). Thus, it is unlikely that elevated mainstem temperatures are having a significant impact on juvenile chum salmon.

For the Upper Gorge population, which spawns above Bonneville Dam, passage issues at Bonneville and inundation of historical spawning habitat by Bonneville Reservoir are identified as primary limiting factors.[25] For the Lower Gorge population, the availability of tailrace spawning habitat is affected by flows from the Columbia River hydropower system, with winter and early spring flows being critical to prevent dewatering of redds before emergence.

There are no large tributary dams in the Coast ecozone. In the Cascade and Gorge ecozones, tributary dams are not identified as a primary or secondary limiting factor. Large dam complexes in the Cowlitz and Lewis systems may be affecting chum salmon spawning and rearing conditions by altering habitat-forming processes downstream, but the significance of these effects is unknown (and LCFRB 2010a does not explicitly identify such effects as limiting factors).

### 8.4.4 Harvest Limiting Factors

Historical high harvest rates of chum salmon may have compounded the effects of habitat losses during the last century, but harvest mortality is not considered a baseline or current limiting factor for Columbia River chum salmon. Commercial chum salmon fisheries were closed or drastically reduced in the 1950s. Harvest impacts are limited to illegal harvest and incidental take in lower river commercial gillnet and recreational fisheries (LCFRB 2010a). Commercial fisheries for Chinook and coho salmon occur

[24] It is likely that flow impacts of the hydropower system affect Lower Columbia River ESUs more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

[25] In the 2008 FCRPS Biological Opinion and its 2010 Supplement, NMFS assumed that survival of adult chum passing Bonneville Dam is 96 to 97 percent, based on data for Snake River Fall Chinook salmon (NMFS 2008f and 2010a). It is likely that significant areas of historical chum spawning habitat were inundated by Bonneville Reservoir.

before adult chum salmon return in the late fall. Harvest-related mortality of chum salmon has been less than 5 percent per year since 1993 (LCFRB 2010a) and has averaged 1.6 percent annually since 1998 (ODFW 2010).

### 8.4.5 Hatchery-Related Limiting Factors

Chum salmon have never been subject to significant hatchery production in the Columbia River for fishery mitigation programs. Hatchery-related factors were not identified as limiting for any Oregon chum salmon population. ODFW began releasing chum salmon into the Big Creek subbasin in 2011 as part of a reintroduction program, using Grays River chum salmon as broodstock. In Washington, conservation hatchery programs are being used to supplement natural production in the Grays/Chinook and Lower Gorge populations. Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish were identified as a secondary limiting factor for the Grays/Chinook chum salmon, where analysis by the regional Hatchery Scientific Review Group estimated an 11 percent reduction in productivity; however, the HSRG analysis did not consider the positive demographic effects of increased natural spawning abundance through hatchery supplementation. Conservation hatchery programs are identified as a key component of reintroduction and recovery efforts for chum salmon populations in Oregon and Washington.

It is possible that juvenile chum salmon rearing in the estuary are affected by hatchery-origin Chinook, steelhead, and coho juveniles. Potentially detrimental interactions include competition for food and space. However, differences in life history patterns may moderate effects, and the significance of interactions is unknown. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

### 8.4.6 Predation Limiting Factors

Predation by hatchery smolts in the estuary is identified as a secondary limiting factor for all Columbia River chum salmon. Chum salmon fry from all populations may experience predation by hatchery-origin coho, steelhead, and Chinook smolts, although differences in life history patterns may moderate effects, and the significance of interactions is unknown. In addition, predation by non-salmonid fish is identified as a secondary limiting factor for the Upper Gorge population. Although the extent of chum salmon production above Bonneville is unknown, fish spawning above the dam would experience predation by pikeminnow above and below Bonneville Dam and by walleye and smallmouth bass in the reservoir behind the dam.

## 8.5 Baseline Threat Impacts and Reduction Targets

Table 8-4 shows the estimated impact on each Washington Columbia River chum salmon population resulting from potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. The table also shows the overall percentage improvement that is needed to achieve the target impacts and corresponding population status.[26] These cumulative values across all threat categories (both baseline and target) are multiplicative rather than additive. Both the Oregon and Washington management unit plans use cumulative survivals across threat categories to illustrate the overall level of improvement needed. Each plan assumes that there is a direct proportional relationship between the projected changes in cumulative survival and the required changes in natural-origin spawner abundance and productivity. For populations where the survival improvement needed is larger than 500 percent, Table 8-4 does not report the exact value, in part because the value is highly uncertain.[27]

As an example, the baseline status of the Elochoman/Skamakowa chum salmon population, circa 1999, has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 93.3 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 6.7 percent of the historical potential with no human impact. Tributary and estuary habitat impacts each accounted for reductions in population productivity of 25 percent or more, with corresponding reductions in abundance, spatial structure, and diversity. The Washington management unit plan identifies a recovery strategy involving significant reductions in the impact of habitat-related threats. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 90 percent to 45 percent (i.e., an approximately 100 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 93.3 percent at baseline to 55 percent at the target status. This change would translate into a more than 500 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

[26] The percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts is taken from Table 6-7 of LCFRB (2010a). For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 8.5.

[27] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

Baseline impacts reflect conditions prevalent at the time of ESA listing (circa 1999). Dam impacts reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas. Hatchery impacts were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009). Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. In general, the tributary habitat values in Table 8-4 have the highest degree of uncertainty relative to the other threat categories. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 8-4 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts in Table 8-4 represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 8-4 reflect policy decisions and the methodologies and assumptions used by the management unit recovery planners. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of chum salmon exposed to that particular category of threats, whether or not they are exposed to threats in other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[28] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 8-4, most of the gains in the viability of Washington chum salmon populations are targeted to be achieved by improving tributary and estuarine habitat. Because potentially manageable harvest, hatchery, and predation impacts on chum salmon already are relatively low, there is little opportunity to further reduce threats in these sectors. Hydropower actions also are projected to benefit the Upper Gorge population, which is affected by Bonneville Dam and its reservoir.

[28] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

Oregon recovery planners did not develop current and target threat impacts for chum salmon populations because quantitative information for use in calculating baseline or target threat impacts or the likelihood of recovery goals being achieved was not available (ODFW 2010). Recovery planners developed a chum salmon recovery strategy that involves identifying specific habitat needs and proceeding with reintroduction, initially in the Coast stratum (see Appendix I of ODFW 2010).

More information on threat reduction scenarios, including methodologies to determine baseline and target impacts, is available in the management unit plans (ODFW 2010 p. 152 and LCFRB 2010a pp. 4-30 through 4-33 and 6-37 through 6-40).

## Table 8-4

*Impacts of Potentially Manageable Threat, and Impact Reduction Targets Consistent with Recovery of Columbia River Chum Salmon (Washington Populations Only[29])*

| Washington Population | Impacts at Baseline[30] | | | | | | | Impacts at Target | | | | | | | % Survival Improvement Needed[38] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[31] | Est[32] | Dams[33] | Harv[34] | Hat[35] | Pred[36] | Cumul-ative[37] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumul-ative | |
| **Coast** | | | | | | | | | | | | | | | |
| Grays/Chinook | 0.80 | 0.25 | 0.00 | 0.05 | 0.11 | 0.03 | 0.8770 | 0.80 | 0.25 | 0.00 | 0.05 | 0.11 | 0.03 | 0.8770 | 0% |
| Eloch/Skam | 0.90 | 0.25 | 0.00 | 0.05 | 0.03 | 0.03 | 0.9330 | 0.45 | 0.13 | 0.00 | 0.03 | 0.01 | 0.02 | 0.5497 | >500% |
| Mill/Ab/Germ | 0.90 | 0.25 | 0.00 | 0.05 | 0.03 | 0.03 | 0.9330 | 0.45 | 0.13 | 0.00 | 0.03 | 0.01 | 0.02 | 0.7497 | >500% |
| **Cascade** | | | | | | | | | | | | | | | |
| Cowlitz (Fall) | 0.96 | 0.25 | 0.00 | 0.05 | 0.02 | 0.03 | 0.9729 | 0.48 | 0.13 | 0.00 | 0.03 | 0.01 | 0.02 | 0.5742 | >500% |
| Cowlitz (Summer) | 0.96 | 0.25 | 0.00 | 0.05 | 0.02 | 0.03 | 0.9729 | 0.48 | 0.13 | 0.00 | 0.03 | 0.01 | 0.02 | 0.5742 | >500% |
| Kalama | 0.90 | 0.25 | 0.00 | 0.05 | 0.01 | 0.03 | 0.9316 | 0.45 | 0.13 | 0.00 | 0.03 | 0.00 | 0.02 | 0.5451 | >500% |
| Lewis | 0.90 | 0.25 | 0.00 | 0.05 | 0.01 | 0.03 | 0.9316 | 0.45 | 0.13 | 0.00 | 0.03 | 0.01 | 0.02 | 0.5497 | >500% |
| Salmon Creek | 0.98 | 0.25 | 0.00 | 0.05 | 0.01 | 0.03 | 0.9863 | 0.98 | 0.25 | 0.00 | 0.05 | 0.01 | 0.03 | 0.9863 | 0% |
| Washougal | 0.96 | 0.25 | 0.00 | 0.05 | 0.01 | 0.03 | 0.9863 | 0.48 | 0.13 | 0.00 | 0.03 | 0.01 | 0.02 | 0.5742 | >500% |

[29] Oregon populations are not included in this table because data are not available to quantify the baseline or target threat impacts for these populations.
[30] Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. See Sections 5.5 and 5.6 for information on methodologies.
[31] Reduction in tributary habitat production potential relative to historical conditions.
[32] Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.
[33] Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas.
[34] Includes direct and indirect mortality.
[35] Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.
[36] Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.
[37] Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1-[(1-M_{thab})(1-M_{est})(1-M_{dams})(1-M_{harv})(1-M_{hatch})(1-M_{pred})])$.
[38] Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are taken from Table 6-7 of LCFRB (2010a). For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 8.5.

## Table 8-4

*Impacts of Potentially Manageable Threat, and Impact Reduction Targets Consistent with Recovery of Columbia River Chum Salmon (Washington Populations Only[29])*

| Washington Population | Impacts at Baseline[30] | | | | | | | Impacts at Target | | | | | | | % Survival Improvement Needed[38] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[31] | Est[32] | Dams[33] | Harv[34] | Hat[35] | Pred[36] | Cumul-ative[37] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumul-ative | |
| **Gorge** | | | | | | | | | | | | | | | |
| Lower Gorge—WA portion | 0.40 | 0.25 | 0.30 | 0.05 | 0.01 | 0.03 | 0.7126 | 0.40 | 0.25 | 0.30 | 0.05 | 0.01 | 0.03 | 0.7126 | 0% |
| Upper Gorge—WA portion | 0.97 | 0.25 | 0.96 | 0.05 | 0.01 | 0.03 | 0.9992 | 0.49 | 0.13 | 0.48 | 0.03 | 0.00 | 0.02 | 0.7807 | >500% |

## 8.6 ESU Recovery Strategy for Columbia River Chum Salmon

This section describes the recovery strategy for Columbia River chum salmon. A general summary of the ESU-level strategy is presented first. This is followed by subsections on each of the threat categories and critical uncertainties that pertain to the strategy. Where appropriate, stratum-specific strategies are described for each threat category.

### 8.6.1 Strategy Summary

The ESU recovery strategy for Columbia River chum salmon focuses on improving tributary and estuarine habitat conditions, reducing or mitigating hydropower impacts, and reestablishing chum salmon populations where they may have been extirpated. The goal of the strategy is to increase the abundance, productivity, diversity, and spatial structure of chum salmon populations such that the Coast and Cascade chum salmon strata are restored to a high probability of persistence and the persistence probability of the two Gorge populations is improved (including achieving a high persistence probability for the Lower Gorge population). The ESU recovery strategy has the following main elements:

1. Protect and improve the Grays/Chinook and Lower Gorge populations, which together produce the majority of Columbia River chum salmon (LCFRB 2010a) and are the only populations in the ESU not currently at very high risk of extinction.

2. Identify, protect, and restore chum salmon spawning habitat in lower mainstem and off-channel areas of large rivers and streams that are fed by upwelling from intergravel flows or springs. Restore hydrologic, riparian, and sediment processes (e.g., large woody debris recruitment) that support the accumulation of spawning gravel and reduce inputs of fine sediment.

3. Restore off-channel and side-channel habitats (alcoves, wetlands, floodplains, etc.) in the Columbia River estuary, where chum salmon fry rely on peripheral and transitional habitats for extended estuarine rearing.

4. Use hatchery reintroduction as appropriate in reestablishing chum salmon populations and continue using supplementation to enhance the abundance of the Grays/Chinook and Lower Gorge populations.

Restoring tributary spawning and estuary rearing habitat is essential in the recovery of Columbia River chum salmon. Although the recovery strategy includes other components, no other factor can effectively bring about recovery (LCFRB 2010a).

The Oregon management unit plan's description of a systematic, adaptive approach to chum salmon recovery can be viewed as a template for the ESU. The approach involves (1) identifying, assessing, and protecting existing chum salmon habitat, especially in currently productive areas, (2) restoring spawning and rearing habitat in all ecozones as

needed to support recovered populations,[39] (3) reestablishing populations in selected subbasins, (4) monitoring to evaluate the program and allow for adaptive management, and (5) applying successful techniques elsewhere (see ODFW 2010, Appendix I). Oregon intends to focus initial efforts on the Clatskanie and Scappoose populations and then, based on results in those populations, expand efforts to populations in the Cascade and Gorge ecozones. Washington intends to focus initial efforts on the Elochoman-Skamokawa, Mill/Abernathy/Germany, Lewis, and Washougal populations.

Reestablishing chum salmon populations could occur through recolonization or hatchery reintroduction. Recolonization is the process of fish from other populations straying into a subbasin and spawning successfully; this may lead to the establishment of self-sustaining, locally adapted populations. If chum salmon abundances are so low that recolonization cannot occur, hatchery reintroduction may have a higher likelihood of success. For either method to be successful, the factors that led to extirpation will need to have been addressed—thus the emphasis on habitat assessment and restoration.

As part of a series of 3- to 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation).

Key critical uncertainties that need to be addressed to support implementation of near-term actions for chum salmon relate to current population status, estuarine habitat requirements, the extent and location of currently or potentially suitable habitat, and the effectiveness of hatchery reintroduction compared to natural recolonization (see Section 8.6.8).

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a, ODFW 2010, NMFS 2013).

### 8.6.2 Tributary Habitat Strategy

Tributary habitat protection and improvement are essential to the recovery of Columbia River chum salmon, which will benefit from the regional tributary habitat strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific management actions that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions that will repair habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. The management unit plans set a high priority on identifying and improving chum salmon spawning habitat, reducing the impacts of sediment on survival to emergence, and improving juvenile rearing habitat.[40] Because of a lack of habitat data in Oregon specific to chum salmon, physical

[39] Recovery plan implementers will look for opportunities to combine chum habitat restoration efforts with those for fall Chinook, to increase efficiency.

[40] Because chum salmon leave tributary habitat at a very early age, improving estuarine habitats will also be essential to improving juvenile rearing habitats for chum salmon.

assessments are needed to identify areas for reintroduction, estimate carrying capacity, and identify habitat in need of immediate restoration. Key habitats to be protected or restored for chum salmon include lower mainstem and off-channel areas of large rivers and streams fed by upwelling from intergravel flows or springs. Protecting key production areas in the Grays River and Columbia River mainstem will be critical.

Near-term habitat improvements will depend on implementation of high-priority tributary actions that are identified in the management unit plans, completion of recovery plan implementation schedules—including a prioritization and sequencing framework for additional habitat actions—and completion of additional assessment work. The Oregon management unit plan recommends that physical habitat surveys be initiated as soon as possible to determine the quality and quantity of chum salmon spawning habitat for the entire historical range of chum salmon in Oregon if funding is available but with priority given to areas of high intrinsic habitat potential in the Scappoose and Clatskanie subbasins if funds are limited (ODFW 2010, Appendix I).

Priority site-specific actions for chum salmon will focus on protecting, restoring, or creating lowland floodplain function, riparian function, and stream habitat complexity. Priority restoration projects will include those to create or improve access to off-channel and side-channel habitat (alcoves, wetlands, floodplains, etc.) and restore riparian areas and instream habitat complexity; this includes improving recruitment of large wood to streams. The Washington management unit plan also identifies the creation of chum salmon spawning channels as a priority short-term action. The subsections below summarize additional, stratum-specific tributary habitat strategies for Columbia River chum salmon.

Ultimately, restoration of adequate habitat for chum salmon will be challenging because of the high proportion of habitat in private ownership.

#### *8.6.2.1 Coast-Stratum Tributary Habitat Strategies*

In implementing the Columbia River chum salmon strategy in the Coast stratum, considerations include the following:

- Protecting the existing production areas in the Grays River will be key. The Grays/Chinook chum salmon population is a core and genetic legacy population and one of only two populations in the ESU with appreciable natural production.

- Lowland areas are primarily in agricultural or rural residential use. These areas have been extensively modified by dikes, levees, bank stabilization, and tide gates; efforts to protect and restore habitat complexity will be priorities here. Actions will include breaching, lowering, or relocating dikes and levees where possible to improve access to off-channel habitats for juvenile chum salmon, particularly in the Clatskanie, Scappoose, Grays, and Mill/Abernathy/Germany, and Elochoman/Skamokowa subbasins (ODFW 2010, LCFRB 2010a).

- Upland areas are predominantly state and private timber land; these lands must be managed to protect and restore watershed processes.

- Physical habitat surveys are needed to determine the quality and quantity of chum salmon spawning habitat within high intrinsic potential areas of the Scappoose and Clatskanie subbasins. Assessments should include evaluations of gravel quality, hyporheic flow, upwelling, and water quality conditions (temperature, suspended sediments dissolved oxygen, etc.).

- Sediment source analyses and implementation of actions to reduce sediment will be needed in most Coast-stratum tributaries.

In addition to the actions described as part of the regional strategy for tributary habitat, the Oregon plan identifies a need to investigate whether headwater springs in the Youngs Bay, Big Creek, Clatskanie, and Scappoose subbasins are drying up as a result of land management practices. The Oregon management unit plan also emphasizes the almost universal deficiency of large woody debris in the Coast ecozone as a contributing factor to the inability of individual stream systems to sort and store gravel suitable for use by chum salmon.

Assuming that the impacts of other threats are reduced to the levels shown in Table 8-4, habitat improvements of up to 50 percent will be needed for some Washington Coast-stratum chum salmon populations. Significant habitat actions will be needed in all areas to protect existing habitats. Habitat improvement targets for Oregon chum salmon populations were not quantified because of a lack of baseline habitat and population data for chum salmon.

#### *8.6.2.2 Cascade-Stratum Tributary Habitat Strategies*

In implementing the Columbia River chum salmon habitat strategy in the Cascade stratum, considerations include the following:

- In the lower reaches of most Cascade subbasins, including the Lower Cowlitz, North Fork Lewis, East Fork Lewis, Salmon Creek, and Clackamas, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development, agricultural land, and, in some cases, gravel mining. Restoration of these areas will need to be balanced with the need to protect existing infrastructure and control flood risk. Restoring floodplain function and habitat complexity in these areas is crucial in restoring chum salmon spawning and rearing habitat.

- Upper portions of the East Fork Lewis, Washougal, Clackamas, and Sandy subbasins are primarily federal forest lands. Continued implementation of the Northwest Forest Plan will be crucial in protecting and restoring watershed processes in these areas.

- State or private forest land predominates in the upper portions of the Kalama, North Fork Lewis, and Salmon Creek subbasins. These lands must be managed to protect and restore watershed processes.

- The stratum includes the most heavily urbanized areas in the Columbia Basin. Managing the impacts of growth and development on watershed processes and

habitat conditions will be key to the protection and improvement of habitat conditions for chum salmon in these areas.

- Physical habitat surveys are needed to determine the quality and quantity of chum salmon spawning habitat within areas of high intrinsic potential. Assessments should include evaluations of gravel quality, hyporheic flow, upwelling, and water quality conditions (temperature, suspended sediments dissolved oxygen, etc.).

Sediment issues will be addressed generally by restoring watershed processes and dealing with legacy road issues. In some cases (e.g., the Sandy), assessment to identify sediment sources is noted as a first step before additional actions can be taken. The Oregon management unit plan also includes actions to address flow issues in the Clackamas subbasin and roadway-related passage issues in lower Sandy river tributaries. Implementation of the city of Portland's Bull Run Water Supply habitat conservation plan will include habitat restoration in the Sandy River delta and lower reaches that will improve habitat for chum salmon.

Assuming that the impacts of other threats are reduced to the levels shown in Table 8-4, the scale of habitat improvements needed for Washington Cascade chum salmon populations ranges from minimal for the Salmon Creek population to a 50 percent reduction in habitat impacts in other Washington populations. Habitat improvement targets for Oregon chum salmon populations were not quantified because of a lack of baseline habitat and population data for chum salmon.

#### *8.6.2.3 Gorge-Stratum Tributary Habitat Strategies*

In implementing the Columbia River chum salmon habitat strategy in the Gorge stratum, considerations include the following:

- It is likely that significant amounts of historical chum spawning habitat for the Upper Gorge population have been inundated by Bonneville Reservoir.

- In the lower reaches of most Gorge streams, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development and transportation infrastructure. For the Upper Gorge population, site-specific actions will include addressing or mitigating the impacts of the highway and railroad transportation corridors that run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes.

- Upper portions of some Gorge tributaries are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.

- Physical habitat surveys are needed to determine the quality and quantity of chum salmon spawning habitat within areas of high intrinsic potential. Assessments should include evaluations of gravel quality, hyporheic flow,

upwelling, and water quality conditions (temperature, suspended sediments dissolved oxygen, etc.).

Restoring floodplain connectivity and function is called for at locations below Bonneville Dam; however, there is little opportunity to implement these floodplain measures above Bonneville Dam because much floodplain habitat was inundated by Bonneville Reservoir. For this reason, habitat efforts above the dam will rely on other strategies.

Assuming that the impacts of other threats are reduced to the levels shown in Table 8-4, reductions in baseline tributary habitat impacts needed to meet target statuses range from minimal for the Upper Gorge population to a 50 percent reduction in habitat impacts for the Washington portion of the Lower Gorge population. Habitat improvement targets for Oregon chum salmon populations were not quantified because of a lack of baseline habitat and population data for chum salmon.

### 8.6.3 Estuary Habitat Strategy

Estuarine habitat improvements are likely to be critical for Columbia River chum salmon, which leave their natal tributaries at a very early age and are thought to be severely limited by a paucity of intertidal marshes and similar estuarine wetlands needed for refuge and extended rearing. Habitat analysis for fall Chinook salmon indicates that populations in the Coast ecozone historically relied on wetland areas at the confluences of the tributaries and the mainstem Columbia (Northwest Fisheries Science Center 2010); because the habitat needs of fall Chinook and chum salmon appear to overlap considerably, some NMFS scientists have suggested that these same confluence areas may also be significant for chum salmon.

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Columbia River chum salmon. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2.) The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). For Columbia River chum salmon, the assessment process described as part of the regional strategy should include assessment of the tidal portions of tributaries and their confluence with the mainstem Columbia. Developing implementation priorities for estuarine habitat actions also should include establishment of milestones or expected trends in improved habitat conditions in high-priority intertidal areas.

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of outmigrating juveniles leaving the Columbia River estuary. Washington recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for chum salmon populations based on the estuary module and their own approach to threat reductions (LCFRB 2010a, Table 6-7). Oregon did not quantify baseline and target threat impacts for chum salmon populations because data were inadequate to do so.

Ultimately, restoring adequate habitat for chum salmon in the Columbia River estuary will be challenging because of the high proportion of habitat in private ownership.

### 8.6.4 Hydropower Strategy

Chum salmon are expected to benefit from the regional hydropower strategy (see Section 4.3.2), which involves improving passage survival at Bonneville Dam for the Upper Gorge populations and, specifically for chum salmon, ensuring adequate flows in the Bonneville Dam tailrace and downstream throughout migration, spawning, incubation, and emergence. In addition, NMFS expects that implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. Because Columbia River chum salmon are distributed low in tributary subbasins, reintroduction above tributary dam complexes is not part of the recovery strategy.

NMFS estimates that survival of Columbia River chum salmon passing Bonneville Dam was 95.1 percent for juveniles from 2002 to 2009 and 96.9 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expects that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will improve juvenile chum salmon survival at Bonneville Dam by less than ½ percent, and that adult survival will be maintained at recent high levels (NMFS 2008a). Consequently, Oregon has not incorporated survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[41] The Washington management unit plan assumes that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement will aid adults and juveniles from all chum salmon populations originating above Bonneville Dam.

FCRPS Biological Opinion actions also will provide adequate conditions for chum salmon spawning in the mainstem Columbia River in the area of the Ives Island complex and/or access to the Hamilton and Hardy Creeks to protect spawning areas for the Lower Gorge population.

For information on how hydropower operations will improve the survival of chum salmon in the Columbia River estuary, see the regional hydropower strategy in Section 4.3.2.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon

[41] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, including their potential to benefit chum salmon, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for chum salmon.

#### *8.6.4.1 Coast-Stratum Hydropower Strategies*

There are no tributary dams in the Coast ecozone, so the hydropower strategy for the Coast stratum is to implement the flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations.

#### *8.6.4.2 Cascade-Stratum Hydropower Strategies*

Tributary dams in the Cascade ecozone are not identified as limiting factors for Cascade chum salmon populations, so the hydropower strategy for the Cascade stratum is to implement the mainstem hydropower actions that are expected to improve estuarine and, potentially, plume survival for all Columbia River chum salmon populations. The quantity and quality of spawning and rearing habitat for chum salmon in the North Fork Lewis and Cowlitz are affected by the rate at which water is discharged at Merwin and Mayfield dams, respectively. The operational plans for the Lewis and Cowlitz dams, in conjunction with fish management plans, should include flow regimes (minimum flow and ramping rate requirements, etc.) that enhance the lower river habitat for chum salmon.

#### *8.6.4.3 Gorge-Stratum Hydropower Strategies*

Tributary dams do not affect the Lower Gorge or Upper Gorge populations. Reductions in passage impacts at Bonneville Dam, as outlined in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a), are expected to provide slight benefits to the Upper Gorge population, and the FCRPS will be operated to provide adequate conditions for chum salmon spawning in the mainstem Columbia River below Bonneville Dam (i.e., the Lower Gorge population). For more information, see the regional hydropower strategy in Section 4.3.2.

### 8.6.5 Harvest Strategy

The harvest strategy for chum salmon is to avoid significant increases in the current very low incidental fishery impacts by continuing to limit mainstem and tributary recreational fisheries for other species (primarily hatchery late-fall Chinook and coho) in times and areas where chum salmon are present. The Washington management unit plan identifies targets for reductions in impacts of all threat categories based on a strategy of equitable sharing of the recovery burden. Thus, the Washington plan describes fishery impact reductions from the 5 percent baseline rate for chum salmon at

the time of listing. However, the current incidental fishery impact rate of 2 percent or less per year meets impact reduction targets identified in the Washington management unit plan (LCFRB 2010a).

### 8.6.6 Hatchery Strategy

The hatchery recovery strategy for Columbia River chum salmon is to use hatcheries to supplement and reduce risks to natural populations as appropriate, and to use hatchery reintroduction as appropriate to reestablish populations where they have been extirpated or nearly so. Reintroduction using hatchery chum salmon would be coordinated with habitat protection and restoration and triggered by a determination that natural chum salmon abundances are so low that recolonization would likely not be successful. Steps in the reintroduction strategy are to identify and obtain suitable broodstock, identify facilities for use in the conservation hatchery program, identify production goals and program duration, identify artificial production techniques, and identify release strategies for the reintroduction program. Experimental supplementation and reintroduction programs will be accompanied by aggressive monitoring and evaluation programs.

#### *8.6.6.1 Coast-Stratum Hatchery Strategy*

In the Coast stratum, the hatchery strategy is to continue the existing hatchery supplementation program and expand supplementation or reintroduction to other populations as deemed appropriate. The Grays River hatchery program produces chum salmon to augment natural production and reduce extinction risks to naturally spawning Grays River chum salmon. This program occurs in conjunction with habitat restoration efforts in the Grays subbasin. The program also is considered an important safety net for chum in the lower Columbia in general (LCFRB 2010a, Volume II).

Oregon also recently initiated a chum salmon hatchery program at its Big Creek hatchery, using Grays River fish as broodstock. Chum salmon from this program were first released into the Big Creek subbasin in 2011 as part of a reintroduction program. The Oregon management unit plan's chum salmon recovery strategy focuses initially on the Coast stratum. This is because the Coast-stratum subbasins are believed to have been less altered by human development than subbasins in other strata; thus Coast-stratum subbasins provide the best opportunity to test hypotheses regarding re-establishing self-sustaining chum salmon populations. (Oregon will use lessons learned from chum salmon recovery efforts in the Coast stratum to inform efforts to improve or create habitat and to reestablish chum salmon throughout the ESU.)

No hatchery chum salmon are currently released into other Coast-stratum subbasins, although other reintroduction or supplementation programs may be developed.

#### *8.6.6.2 Cascade-Stratum Hatchery Strategy*

In the Cascade stratum, the hatchery strategy is to develop supplementation or reintroduction programs for Cascade-stratum populations as deemed appropriate. Currently, no hatchery chum salmon are released in the Cascade stratum. (The Washougal hatchery produces chum salmon for an enhancement program to assist in

rebuilding of the Lower Gorge chum salmon population). The Washington management unit plan notes that for the Cascade populations, one potential hatchery strategy is to develop a chum salmon broodstock using natural returns or some other appropriate population but does not lay out any timelines or decision points for that strategy. The Oregon management unit plan will focus efforts first in the Coast stratum and use lessons learned there to inform efforts to improve or create habitat and to reestablish chum salmon throughout the ESU.

#### *8.6.6.3 Gorge-Stratum Hatchery Strategy*

In the Gorge stratum, the hatchery strategy is to continue the existing hatchery supplementation program and expand supplementation or reintroduction as deemed appropriate. Currently, no hatchery chum salmon are produced in the Gorge stratum; however, the Washougal hatchery produces chum salmon for an enhancement program to assist in rebuilding the Lower Gorge population. This program uses chum salmon spawning in the Ives Island area for broodstock with a goal of enhancing chum salmon returns to Duncan Creek. The program occurs in conjunction with habitat restoration efforts in Duncan Creek. This program also acts as a safety net in the event that mainstem Columbia flow operations severely limit the natural spawning of chum salmon in Hamilton and Hardy creeks and in the Ives Island area below Bonneville Dam. The Washington management unit plan also notes the possibility of using a conservation hatchery program for the Upper Gorge population. The Oregon management unit plan will focus chum salmon recovery efforts first in the Coast stratum and use lessons learned there to inform efforts to improve or create habitat and to reestablish chum salmon throughout the ESU.

### 8.6.7 Predation Strategy

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia ESUs, including Columbia River chum salmon.

### 8.6.8 Critical Uncertainties

Each aspect of the chum salmon recovery strategy has a number of critical uncertainties, including the overarching questions of why some chum salmon populations are performing better than others and what the implications of these differences are with respect to recovery. To answer these questions, additional data are needed on chum salmon population characteristics, habitat usage and availability, interspecies predation on chum salmon juveniles, and hatchery reintroductions of chum salmon. In addition, for all ESUs there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to the Columbia River chum salmon recovery strategy include the following:

- Historical role of the Gorge populations and appropriate target persistence probabilities, and abundance and productivity targets for them.

- Total adult spawning escapement, adult productivity, juvenile survival, and life history diversity of Columbia River chum salmon populations;
- Chum salmon's estuarine habitat requirements and how they overlap with those of fall Chinook
- Extent to which chum salmon use intertidal estuary-tributary "confluence" habitats and, if so, whether they are the same habitats used by fall Chinook
- Current extent of suitable or potentially suitable chum salmon habitat
- Best locations for restoration of chum salmon spawning habitat
- Effectiveness (both short term and long term) of constructed chum salmon spawning channels as a restoration strategy
- Relative effectiveness of hatchery reintroduction, hatchery supplementation, and natural recolonization in reestablishing and recovering chum salmon populations
- Significance of ecological interactions between hatchery- and natural-origin fish, such as predation by steelhead and coho on chum salmon (LCFRB 2010a)
- Potential for incidental harvest of chum salmon to increase in terminal fishing areas as chum salmon are reintroduced in Oregon and populations increase

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10, additional discussion among local recovery planners and NMFS staff will be needed to finalize future research and monitoring priorities for chum salmon.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with list above, will provide the basis for these future discussions. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the Lower Columbia Fish Recovery Board completed the *Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties—and Section 8.6.4 of ODFW (2010) lists research, monitoring, and evaluation needs to address uncertainties related to Oregon's chum salmon recovery strategy. The list above does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are

of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the chum salmon recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

## 8.7 Delisting Criteria Conclusion for Columbia River Chum Salmon

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Columbia River chum salmon ESU from the Federal List of Endangered and Threatened Wildlife and Plants (that is, to delist the ESU), NMFS must determine that the ESU, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12). The biological and threats criteria in this plan, taken together, meet this statutory requirement.

As described in Section 8.3, if the scenario in Table 8-2 were achieved, it would slightly exceed the WLC TRT's viability criteria in the Coast and Cascade strata (in the latter case, the scenario would exceed the criterion for number of populations but just meet the scoring criterion) (see Table 8-5). However, the scenario would not meet criteria in the Gorge stratum because only one Gorge population (the Lower Gorge) would be viable, instead of two (see Table 8-5).[42] Exceeding the criteria in the Coast and Cascade strata was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge stratum.

[42] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher.

**Table 8-5**
*Chum Salmon Recovery Scenario Scores Relative to WLC TRT's Viability Criteria*

| Species | Number of Primary Populations | | | | | Stratum Average Criteria | | | |
|---|---|---|---|---|---|---|---|---|---|
| Chum | | Coast | Cascade | Gorge | Total | | Coast | Cascade | Gorge |
| | n ≥ high | 5 | 3 | 1 | 9 | Avg. score | 2.29 | 2.25 | 3 |
| | TRT criterion (n ≥ 2) met? | Yes | Yes | No | | TRT criterion (avg. ≥ 2.25) met? | Yes | Yes | Yes |

Source: Based on LCFRB (2010a), Table 4-7.

Recovery planners' uncertainty about meeting WLC TRT criteria in the Gorge chum stratum is based on questions about available habitat and anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of habitat by Bonneville Reservoir) and on questions regarding Gorge strata and population delineations and historical role (LCFRB 2010a, ODFW 2010). These questions include whether the Gorge populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum.

As discussed in Section 3.2, NMFS has considered the WLC TRT's viability criteria (from McElhany et al. 2003 and 2006 and summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios and population-level goals in the management unit plans, and the questions management unit planners raised regarding the historical role of the Gorge stratum.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of an ESU that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the recovery scenario presented in the management unit plans for Columbia River chum salmon (summarized in Table 3-1 of this recovery plan) and the associated population-level abundance and productivity goals (see Section 8.3).

Regarding the divergence of the scenario from the WLC TRT's criteria, the TRT noted in its revised viability criteria (McElhany et al. 2006) the need for case-by-case evaluations of the continuum of ESU-level risk associated with some strata not meeting their criteria. In commenting on the recovery scenarios presented in the interim Washington management unit plan[43]—and by extension the recovery scenarios presented in Table 3-1 of this plan—the WLC TRT stated that achieving the recovery scenarios would improve the status of the Gorge strata, even if the TRT's criteria for those strata were not

[43] In February 2006, NMFS approved the December 2004 version of the Washington management unit plan as an interim regional recovery plan for Lower Columbia River Chinook salmon and steelhead and Columbia River chum salmon. In May 2010, the LCFRB completed a revision of its 2004 plan (LCFRB 2010a), which is incorporated into this ESU-level recovery plan as Appendix B.

met. The TRT also noted that targeting the Cascade stratum for above the minimum TRT criteria would help lower ESU extinction risk. In addition, the TRT noted that the Gorge and Cascade strata are relatively similar compared to the Cascade and Coast strata. Also significant in the TRT's view was that options for recovery of the Gorge stratum would be preserved, in case future conditions or analyses were to require high stratum persistence for ESU viability (McElhany et al. 2006, p. 9).

Based on the information provided by the WLC TRT and the management unit recovery planners, NMFS concludes that the recovery scenarios in Table 3-1 and the associated population-level abundance and productivity goals in Section 8.3 represent one of multiple possible scenarios that would meet biological criteria for delisting. The similarities between the Gorge and Cascade strata, coupled with compensation in the Cascade stratum for not meeting TRT criteria in the Gorge stratum, would provide an ESU no longer likely to become endangered. NMFS endorses the recovery scenario and population-level goals found in the management unit plans for Columbia River chum salmon (summarized in Table 3-1 and Section 8.3) as one of multiple possible scenarios consistent with delisting. As noted earlier in this chapter (see Section 8.3), Oregon did not identify abundance targets for chum salmon populations because data for use in calculating abundance targets and conservation gaps are not available. In this plan (see Table 8-2), NMFS has included placeholder abundance targets for Oregon chum salmon populations based on the minimum abundance thresholds presented in McElhany et al. (2006 and 2007). NMFS expects that these targets will be refined over time as more information becomes available.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and stratum merits further examination. The extent to which compensation in the Cascade stratum is ultimately considered necessary to achieve an acceptably low risk at the ESU level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following biological criteria for the Columbia River chum salmon ESU (NMFS has amended the WLC TRT's criteria to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge stratum):

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition. High probability of stratum persistence is defined as:

    a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

    b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria described in Section 3.2.2 have been met.

# 9. Lower Columbia River Steelhead

## 9.1 Steelhead Biological Background

### 9.1.1 Steelhead Life History and Habitat

Lower Columbia River steelhead (*Oncorhynchus mykiss*) exhibit perhaps the most complex life history of any Pacific salmonid. These fish can be anadromous or freshwater residents (and under some circumstances, apparently yield offspring of the opposite form). Steelhead, the anadromous form of *O. mykiss*, are under the jurisdiction of NMFS, while the resident freshwater forms, usually called "rainbow" or "redband" trout, are under the jurisdiction of the U.S. Fish and Wildlife Service. Steelhead are iteroparous, meaning they can spawn more than once. Repeat spawners are called "kelts."

Two distinct life history types of steelhead—summer and winter runs—historically were and currently are found in the lower Columbia River. The two life history types differ in degree of sexual maturity at freshwater entry, spawning time, and frequency of repeat spawning. Most summer-run steelhead from the Lower Columbia River steelhead DPS re-enter freshwater between May and October and require several months to mature before spawning, generally between late February and early April. Most winter-run steelhead re-enter freshwater between December and May as sexually mature fish; peak spawning occurs later than for summer steelhead, in late April and early May. (See Figures 9-1 and 9-2.) Iteroparity (repeat spawning) rates for Columbia Basin steelhead have been reported as high as 2 to 6 percent for summer steelhead and 8 to 17 percent for winter steelhead populations (Leider et al. 1986, Hulett et al. 1993, and Busby et al. 1996).

Within the same watershed, winter and summer steelhead generally spawn in geographically distinct areas (Myers et al. 2006). Summer steelhead can often reach headwater areas above waterfalls that are impassable to winter steelhead during the high-velocity flows common during the winter-run migration. In basins where both winter and summer steelhead are present, the summer life history strategy appears to be able to persist only above the barrier falls that exclude winter steelhead. Although the summer steelhead's long duration of pre-spawning holding in freshwater enhances their opportunity to take advantage of periodically favorable passage conditions, it may also result in a higher pre-spawning mortality rate that puts summer steelhead at a competitive disadvantage relative to winter steelhead (Myers et al. 2006). Historically, winter steelhead may have been excluded from interior Columbia River subbasins by Celilo Falls.

Steelhead spawn in a wide range of conditions ranging from large streams and rivers to small streams and side channels (Myers et al. 2006). Productive steelhead habitat is characterized by suitable gravel size, depth, and water velocity, and by complexity, primarily in the form of large and small wood (Barnhart 1986). Steelhead may enter streams and arrive at spawning grounds weeks or even months before spawning and therefore are vulnerable to disturbance and predation. They need cover in the form of overhanging vegetation, undercut banks, submerged vegetation, submerged objects

such as logs and rocks, floating debris, deep water, turbulence, and turbidity (Geiger 1973). Their spawning timing must optimize avoiding risks from gravel-bed scour during high flow and increasing water temperatures that can become lethal to eggs. Spawning generally occurs earlier in areas of lower elevation, where water temperature is warmer, than in areas of higher elevation, with cooler water temperature.

Depending on water temperature, steelhead eggs may incubate for 35 to 50 days before hatching, after which alevins remain in the gravel 2 to 3 weeks, until the yolk-sac is absorbed. Generally, emergence occurs from March into July, with peak emergence time generally in April and May. Fry emergence is principally determined by the time of egg deposition and the water temperature during the incubation period. In the Lower Columbia subdomain, emergence timing differs slightly between winter and summer life-history types and among subbasins. These differences may be a function of spawning location (and hence water temperature) or of genetic differences between life-history types.

Following emergence, fry usually move into shallow and slow-moving margins of the stream. As they grow, they inhabit areas with deeper water, a wider range of velocities, and larger substrate, and they may move downstream to rear in large tributaries or mainstem rivers. Young steelhead typically rear in streams for some time before migrating to the ocean as smolts. Steelhead smolts generally migrate at ages ranging from 1 to 4 years, but most steelhead smolt after 2 years in freshwater (Busby et al. 1996). In the lower Columbia River, outmigration of steelhead smolts (of both summer and winter life-history types) generally occurs from March to June, with peak migration usually in April or May.

Catch data suggest that juvenile steelhead migrate directly offshore during their first summer, rather than migrating nearer to the coast. Maturing Columbia River steelhead are found off the coast of Northern British Columbia and west into the North Pacific Ocean (Busby et al. 1996). Fin-mark and coded-wire tag data suggest that winter steelhead tend to migrate farther offshore but not as far north into the Gulf of Alaska as summer steelhead (Burgner et al. 1992). Most steelhead spend 2 years in the ocean (range 1 to 4 years) before migrating back to their natal streams (Shapovalov and Taft 1954, Narver 1969, Ward and Slaney 1988). Once in the river, adult steelhead apparently rarely eat and grow little, if at all.

The key freshwater habitat needs of Lower Columbia River steelhead at different life stages are shown in Table 9-1. Steelhead typically rear in a wider range of stream gradients and average velocities than do other salmon species.

**Table 9-1**
*Key Habitat for Steelhead, by Life Stage*

| Life Stage | Key Habitat Descriptions |
|---|---|
| Spawning | Riffles, tailouts, and glides containing a mixture of gravel and cobble sizes with flow of sufficient depth for spawning activity |
| Incubation | As for spawning, but with sufficient flow for egg and alevin development |
| Fry Colonization | Shallow, slow-velocity areas within the stream channel, often associated with stream margins |
| Active Rearing | Gravel and cobble substrates with sufficient depth and velocity, and boulder/large cobble/wood obstruction to reduce flow and concentrate food |
| Inactive Rearing | Stable cobble/boulder substrates with interstitial spaces |
| Migrant | All habitat types having sufficient flow for free movement of juvenile migrants |
| Pre-Spawning Migrant | All habitat types having sufficient flow for free movement of sexually mature adult migrants |
| Pre-Spawning Holding | Relatively slow, deep-water habitat types (with cool temperatures), typically associated with (or immediately adjacent to) the main channel |

Source: Adapted from Northwest Power and Conservation Council (2004b).

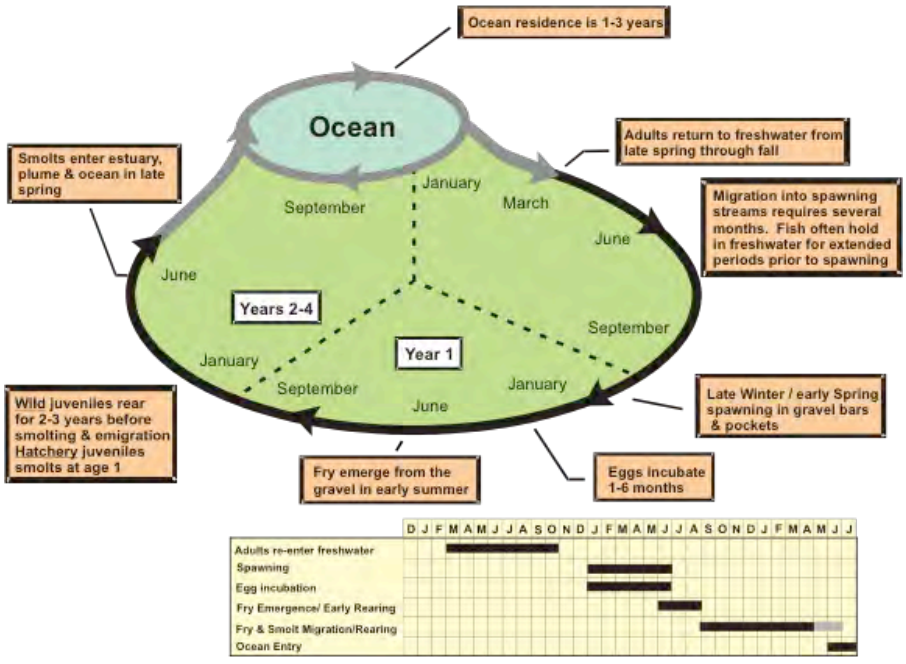


**Figure 9-1.** *Life Cycle of LCR Summer Steelhead*
(Source: LCFRB 2010a)

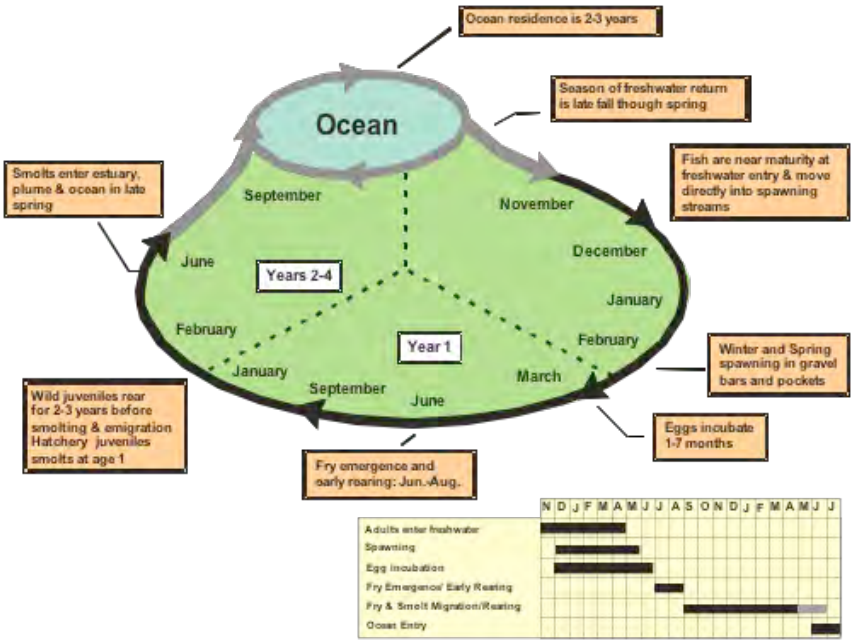


**Figure 9-2.** *Life Cycle of Winter Steelhead*
(Source: LCFRB 2010a)

### 9.1.2 Historical Distribution and Population Structure of LCR Steelhead

The WLC TRT identified 23 historical independent populations of Lower Columbia River steelhead: 17 winter-run populations and six summer-run populations, within the Cascade and Gorge ecozones.[1] Table 9-2 lists these populations and indicates core populations (which historically were highly productive) and genetic legacy populations (which represent important historical genetic diversity). Figures 9-3 and 9-4 show the geographical distribution of Lower Columbia River steelhead strata and populations.

[1] Steelhead populations within the Coast ecozone are part of a separate DPS—the unlisted Southwest Washington DPS—and are not addressed in this recovery plan; however, they are addressed in the Oregon and Washington management unit plans to address state planning needs. The White Salmon and Little White Salmon steelhead populations are part of the Middle Columbia steelhead DPS and are addressed in a separate species-level recovery plan, the *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan* (NMFS 2009a). However, recovery actions for the White Salmon population of Mid-Columbia steelhead are included in the White Salmon management unit plan (*ESA Recovery Plan for the White Salmon River Watershed,* NMFS 2013; see Appendix C of this recovery plan) because this population shares geography with Lower Columbia River coho and Chinook salmon and Columbia River chum in the White Salmon subbasin.

**Table 9-2**
*Historical LCR Steelhead Populations*

| Stratum | Historical Populations | Core or Genetic Legacy Populations |
|---|---|---|
| Cascade summer | Kalama (WA) | Core |
| | NF Lewis (WA) | |
| | EF Lewis (WA) | Genetic legacy |
| | Washougal (WA) | Core, genetic legacy |
| Gorge summer | Wind (WA) | Core |
| | Hood (OR) | |
| Cascade winter | Lower Cowlitz (WA) | |
| | Upper Cowlitz (WA) | Core, genetic legacy |
| | Cispus (WA) | Core, genetic legacy |
| | Tilton (WA) | |
| | SF Toutle (WA) | |
| | NF Toutle (WA) | Core |
| | Coweeman (WA) | |
| | Kalama (WA) | |
| | NF Lewis (WA) | Core |
| | EF Lewis (WA) | |
| | Salmon Creek (WA) | |
| | Clackamas (OR) | Core |
| | Sandy (OR) | Core |
| | Washougal (WA) | |
| Gorge winter | Lower Gorge (WA and OR) | |
| | Upper Gorge (WA and OR) | |
| | Hood (OR) | Core, genetic legacy |

Source: Myers et al. (2006), McElhany et al. (2003).

Up through 2006, ten artificial propagation programs produced steelhead considered to be part of this DPS. In 2007, the release of Cowlitz Hatchery winter steelhead into the Tilton River was discontinued; in 2009, the Hood River winter steelhead program was discontinued; and in 2010, the release of hatchery winter steelhead into the Upper Cowlitz and Cispus rivers was discontinued. In 2011, NMFS recommended removing these programs from the DPS. A Lewis River winter steelhead program was initiated in 2009, and in 2011, NMFS proposed that it be included in the DPS (76 *Federal Register* 50448). Table 9-3 shows the eight steelhead hatchery programs that currently are included in the DPS. For a list of steelhead hatchery programs not included in the DPS, see Jones (2011).

**Table 9-3**
*Artificial Propagation Programs Included in the LCR Steelhead DPS*

| Run Type | Washington Programs | Oregon Programs |
|---|---|---|
| Summer steelhead | Kalama River Wild | Hood River* |
| Winter steelhead | Cowtliz Trout Hatchery - Lower Cowlitz | Clackamas Hatchery |
| | Kalama River Wild | Sandy Hatchery |
| | Lewis River Wild late-run | Hood River |

* The wild summer broodstock program (ODFW stock #50) has been suspended and the non-local summer steelhead program (Skamania stock) terminated.

Source: 71 *Federal Register* 8844, 76 *Federal Register* 50448, and Jones (2011).

## 9.2 Baseline Population Status of LCR Steelhead

Out of the 23 populations in this DPS, 16 are considered to have a low or very low probability of persisting over the next 100 years (see Table 9-4), and six populations have a moderate probability of persistence (LCFRB 2010a, ODFW 2010, Ford 2011).[2] Only the summer-run Wind population is considered viable. Although current Lower Columbia River steelhead populations are depressed compared to historical levels and long-term trends show declines, many populations are substantially healthier than their salmon counterparts, typically because of better habitat conditions in core steelhead production areas (LCFRB 2010a). However, all four strata in the DPS fall short of the WLC TRT criteria for viability.

The low to very low baseline persistence probabilities of most Lower Columbia River steelhead populations reflects low abundance and productivity. In addition, it is likely that genetic and life history diversity has been reduced as a result of pervasive hatchery effects and population bottlenecks. Spatial structure remains relatively high for most populations (LCFRB 2010a, ODFW 2010).

### 9.2.1 Baseline Status of LCR Summer Steelhead

Baseline persistence probabilities were estimated to be low or very low for three out of the six summer steelhead populations that are part of the Lower Columbia River DPS, moderate for two, and high for one—the Wind, which is considered viable (see Figure 9-3) (LCFRB 2010a, ODFW 2010).

[2] As described in Section 2.6, the WLC TRT recommended methods for evaluating the status of Lower Columbia River salmon and steelhead populations. The TRT's approach is based on evaluating the population parameters of abundance, productivity, spatial structure, and diversity and then integrating those assessments into an overall assessment of population persistence probability. As described in Section 5.1, management unit recovery planners evaluated their respective populations' baseline status in a manner generally consistent with the WLC TRT's approach, with the baseline period being either circa 1999 (for Washington populations) or 2006-2018 (for Oregon populations). Unless otherwise noted, NMFS and the management unit planners believe that those assessments accurately reflect the status of the population at that time; the assessments are the basis for the summaries presented here and are consistent with the conclusions of the Northwest Fisheries Science Center in its *Status Review Update for Pacific Salmon and Steelhead Listed under the Endangered Species Act* (Ford 2011). New information on population status will continue to accumulate over time and will be taken into account as needed to reflect the best available science regarding a population's status.

Declines in persistence probability are attributable primarily to low abundance and productivity. Except in the North Fork Lewis subbasin, where dams have impeded access to historical spawning habitat, most summer steelhead populations continue to have access to historical production areas in forested, mid- to-high-elevation subbasins that remain largely intact. It is likely that historical hatchery effects have reduced the genetic diversity of many summer steelhead populations and caused declines in productivity (LCFRB 2010a). The Hood population has the highest proportion of hatchery spawners, at 53 percent (ODFW 2010). The highest pHOS rate among the Washington populations is 35 percent, for the East Fork Lewis (LCFRB 2010a).

### 9.2.2 Baseline Status of LCR Winter Steelhead

Thirteen of the 17 Lower Columbia River winter steelhead populations have low or very low baseline probabilities of persistence, and the remaining four are at moderate probability of persistence (see Figure 9-4) (LCFRB 2010a, ODFW 2010).

Declines in persistence probability are related primarily to low abundance and productivity. In addition, it is likely that historical hatchery effects have reduced the genetic diversity of most winter steelhead populations and caused declines in productivity. Most populations have maintained their spatial structure, meaning that returning adults can access most areas of significant historical habitat (although many of these habitats no longer support significant production) (LCFRB 2010a, ODFW 2010). For the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and Sandy populations, passage to upper basin habitat is partially or entirely blocked by dams (LCFRB 2010a; ODFW 2010); the Upper Gorge population is constrained by hatchery weirs, and the Hood population is constrained by the presence and operation of an irrigation dam. Steelhead distribution has been partially restored in the Upper Cowlitz, Cispus, and Tilton subbasin by trapping and transferring adults and juveniles around impassable dams.

For additional discussion of Lower Columbia River steelhead population status, see the management unit plans (LCFRB 2010a, pp. 6-57 through 6-52, and ODFW 2010, pp. 55-56) and Ford (2011).

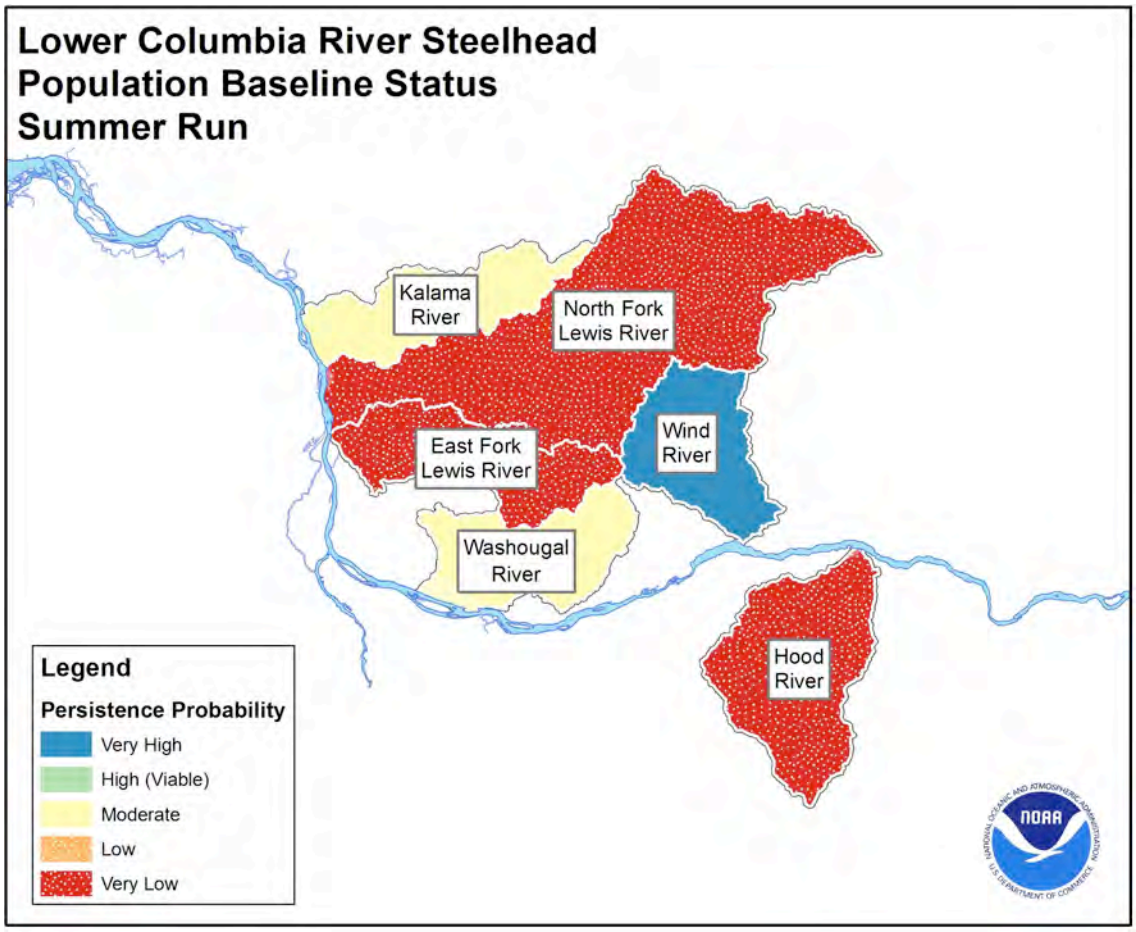


**Figure 9-3.** *Baseline Status of LCR Summer Steelhead Populations*

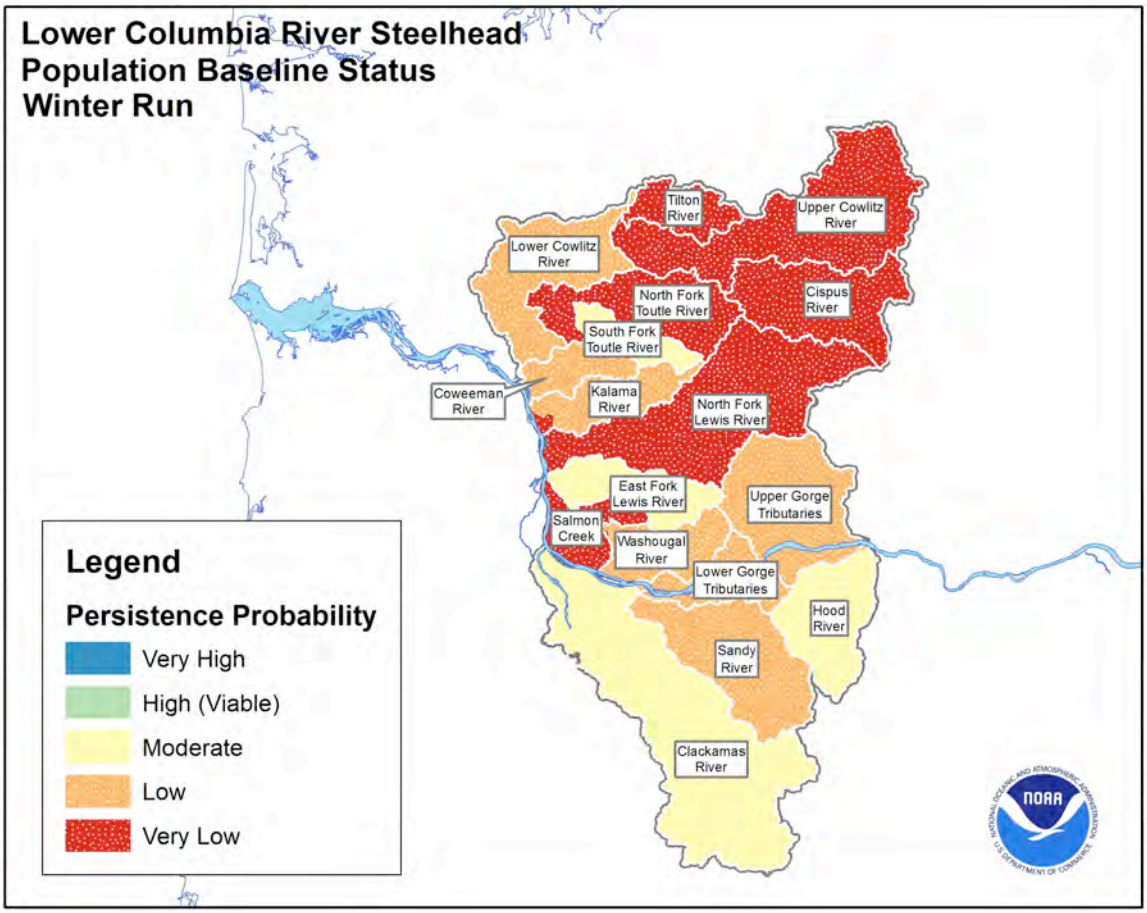


**Figure 9-4.** *Baseline Status of LCR Winter Steelhead Populations*

## 9.3 Target Status and Conservation Gaps for Steelhead Populations

Table 9-4 shows the baseline and target status for each Lower Columbia River steelhead population, along with historical abundance and target abundance. Local recovery planners coordinated with NMFS in making decisions about the target status for each population, taking into consideration opportunities for improvement in view of historical production, current habitat conditions and potential, and the desire to accommodate objectives such as maintaining harvest opportunities. (Note: the target statuses in Table 9-4 are the same as the persistence probabilities in the recovery scenario presented in Table 3-1 in Section 3.13.) As described in Section 5.1, although Oregon and Washington recovery planners used somewhat different methodologies to estimate baseline status and target abundance and productivity NMFS and the management unit planners agree that the methodologies led to similar conclusions regarding the baseline status for Lower Columbia River steelhead populations.

Substantial improvements are needed in the persistence probability of most steelhead populations if the DPS is to achieve recovery (see Figures 9-5 and 9-6). For example, 16 (11 winter and five summer) of 23 historical populations are targeted for high persistence probability or better. Of these, seven of the 17 historical winter-run

populations and two of the six historical summer-run populations have very low or low baseline persistence probabilities. Some level of recovery effort will be needed for every population—even stabilizing populations that are expected to remain at their baseline status—to arrest or reverse continuing long-term declining trends. For most populations, meeting recovery objectives will require improvement in abundance, productivity, and diversity; several populations will also require improvements in spatial structure.

In the Cascade summer steelhead stratum, three of four populations are targeted for high persistence probability. These include the Kalama and Washougal, both large, productive populations historically. Today abundance and productivity in the Kalama population are high, but improvements are needed in spatial structure and diversity. Only one summer steelhead population—the North Fork Lewis—is expected to remain at its baseline status of very low persistence probability; this is because of loss of habitat access related to Merwin Dam, ongoing hatchery programs that produce summer steelhead for harvest, and the desire not to interfere with winter steelhead recovery efforts in the upper North Fork Lewis.

Both populations in the Gorge summer steelhead stratum are designated primary. The Wind population has a high baseline persistence probability and is targeted for very high persistence. The Hood population is targeted to move from very low to high probability of persistence; however, Oregon notes that achieving this target is unlikely (ODFW 2010). Challenges include the small amount of historical and current habitat (and thus the limited options for restoration), anthropogenic impacts that are unlikely to change in the near future (e.g., inundation of historical habitat by Bonneville Reservoir and roads that restrict access to habitat), and high uncertainty in the data and analyses for small populations.[3] The Oregon management unit plan states that most of these issues are related to the population structure designation and suggests re-evaluating the Gorge stratum population structure for all species (ODFW 2010). As discussed in Chapter 3, NMFS agrees that such an evaluation is needed.

In the Cascade winter steelhead stratum, nine of 14 historical populations are targeted for high or better persistence probability. These include the two genetic legacy populations and five of six core populations (those that were historically the most productive). One of these, the Clackamas population, is targeted to move from medium to high persistence probability, but Oregon notes that achieving this target status is unlikely because the level of tributary habitat improvement needed is considered infeasible (ODFW 2010). The sixth core population in this stratum, the North Fork Lewis, is targeted for medium persistence probability. In this stratum, only Salmon Creek, in a highly urbanized subbasin, is expected to remain at its baseline persistence probability of very low.

Of the three populations in the Gorge winter steelhead stratum, two—the Lower Gorge and the Hood (which is both a core and a genetic legacy population)—are targeted for

[3] In the method used by the WLC TRT and management unit planners to establish abundance goals, target abundance is based to some extent on the gap between current and historical abundance. If the historical abundance of Gorge stratum steelhead populations has been significantly overestimated, then the abundance needed to achieve their target status may also be overestimated (ODFW 2010).

high persistence probability. The third, the Upper Gorge, is designated as stabilizing and is expected to remain at its low baseline status because of questions about the historical role of the population and current habitat potential.

If the scenario in Table 9-4 were achieved, it would meet or exceed the WLC TRT's viability criteria, particularly in the Cascade winter stratum but also in the Cascade summer stratum.[4] Exceeding the criteria in the Cascade strata was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge summer stratum.[5] (Delisting criteria for the Lower Columbia River steelhead DPS are described in Sections 3.2 and Section 9.7.)

Figures 9-5 and 9-6 display the population-level conservation gaps for Lower Columbia River steelhead graphically. The conservation gap reflects the magnitude of improvement needed to move a population from its baseline status to the target status. For additional discussion of status targets and conservation gaps for Lower Columbia River steelhead populations, see the management unit plans (LCFRB 2010a, pp. 6-62 through 6-64 and ODFW 2010 pp. 148-150).

[4] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher. In the Cascade winter stratum, nine populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average viability score for all populations in the stratum would be 2.61.

[5] As noted in the discussion above, the Oregon management unit plan stated that achieving the target of high persistence probability for the Clackamas winter population is unlikely because the level of tributary habitat improvement needed is unfeasible. Even if the Clackamas population remained at its baseline status of medium probability of persistence, the Cascade winter steelhead stratum could still meet the WLC TRT's viability criteria for high probability of persistence, assuming adequate improvements in the persistence probability of the other populations in the stratum.

**Table 9-4**

*Baseline and Target Persistence Probability and Abundance of LCR Steelhead Populations*

| | | | Baseline Persistence Probability[6] | | | | | Abundance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stratum** | **Population** | **Contribution** | **A&P** | **S** | **D** | **Net** | **Target Persistence Probability** | **Historical** | **Baseline[7]** | **Target** |
| Cascade summer | Kalama (WA) [C] | Primary | H | VH | M | M | H | 1,000 | 500 | 500 |
| | NF Lewis (WA) | Stabilizing | VL | VL | VL | VL | VL | --[8] | 150 | -- |
| | EF Lewis (WA) | Primary | VL | VH | M | VL | H | 600 | < 50 | 500 |
| | Washougal (WA) [C] | Primary | M | VH | M | M | H | 2,200 | 400 | 500 |
| Gorge summer | Wind (WA) [C] | Primary | VH | VH | H | H | VH | -- | 1,000 | 1,000 |
| | Hood (OR) | Primary | VL | VH | L | VL | H* | 3,822 | 35 | 2,008 |
| Cascade winter | Lower Cowlitz (WA) | Contributing | L | M | M | L | M | 1,400 | 350 | 400 |
| | Upper Cowlitz (WA) [C, GL] | Primary | VL | M | M | VL | H | 1,400 | < 50 | 500 |
| | Cispus (WA) [C, GL] | Primary | VL | M | M | VL | H | 1,500 | < 50 | 500 |
| | Tilton (WA) | Contributing | VL | M | M | VL | L | 1,700 | < 50 | 200 |
| | SF Toutle (WA) | Primary | M | VH | H | M | H+ | 3,600 | 350 | 600 |
| | NF Toutle (WA) [C] | Primary | VL | H | H | VL | H | | 120 | 600 |
| | Coweeman (WA) | Primary | L | VH | VH | L | H | 900 | 350 | 500 |
| | Kalama (WA) | Primary | L | VH | H | L | H+ | 800 | 300 | 600 |
| | NF Lewis (WA) [C] | Contributing | VL | M | M | VL | M | 8,800 | 150 | 400 |
| | EF Lewis (WA) | Primary | M | VH | M | M | H | 900 | 350 | 500 |

[6] A&P = Abundance and productivity, S = spatial structure, and D = genetic and life history diversity. Net = overall persistence probability of the population. VL = very low, L = low, M = moderate, H = high, VH = very high.

[7] Baseline abundance was estimated as described in Section 5.1 and does not equal observed natural-origin spawner counts. The baseline is a modeled abundance that represents 100-year forward projections under conditions representative of a recent baseline period using a population viability analysis that is functionally equivalent to the risk analyses in McElhany et al. (2007). Projections generally assume conditions similar to those from 1974 to 2004. Oregon numbers reflect fishery reductions between the 1990s and about 2004, while Washington numbers reflect fishery impacts prevalent in the period immediately prior to listing in 1999.

[8] "–" indicates that no data are available from which to make a quantitative assessment.

**Table 9-4**

*Baseline and Target Persistence Probability and Abundance of LCR Steelhead Populations*

| | | | Baseline Persistence Probability[6] | | | | | Abundance | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Stratum** | **Population** | **Contribution** | **A&P** | **S** | **D** | **Net** | **Target Persistence Probability** | **Historical** | **Baseline[7]** | **Target** |
| | Salmon Creek (WA) | Stabilizing | VL | H | M | VL | VL | -- | < 50 | -- |
| | Clackamas (OR) [C] | Primary | M | VH | M | M | H* | 21,186 | 3,897 | 10,671 |
| | Sandy (OR) [C] | Primary | L | M | M | L | VH | 11,687 | 674 | 1,519 |
| | Washougal (WA) | Contributing | L | VH | M | L | M | 800 | 300 | 350 |
| Gorge winter | L. Gorge (OR & WA) | Primary | L | VH | M | L | H | -- | 200 | 300 |
| | U. Gorge (OR & WA) | Stabilizing | L | M | M | L | L | -- | 200 | -- |
| | Hood (OR) [C, GL] | Primary | M | VH | M | M | H | 3,822 | 1,127 | 2,079 |

C = Core populations, meaning those that historically were the most productive.

G = Genetic legacy populations, which best represent historical genetic diversity.

*Oregon's analysis indicates a low probability of meeting the delisting objective of high persistence probability for this population.

Source: LCFRB (2010a) and ODFW (2010).

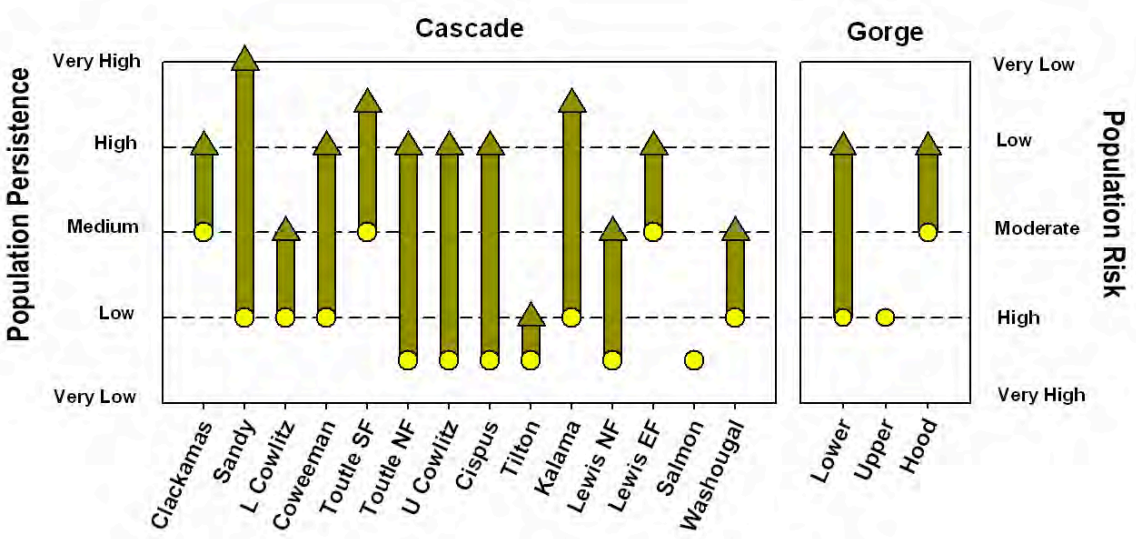


**Figure 9-5.** *Conservation Gaps for LCR Winter Steelhead Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

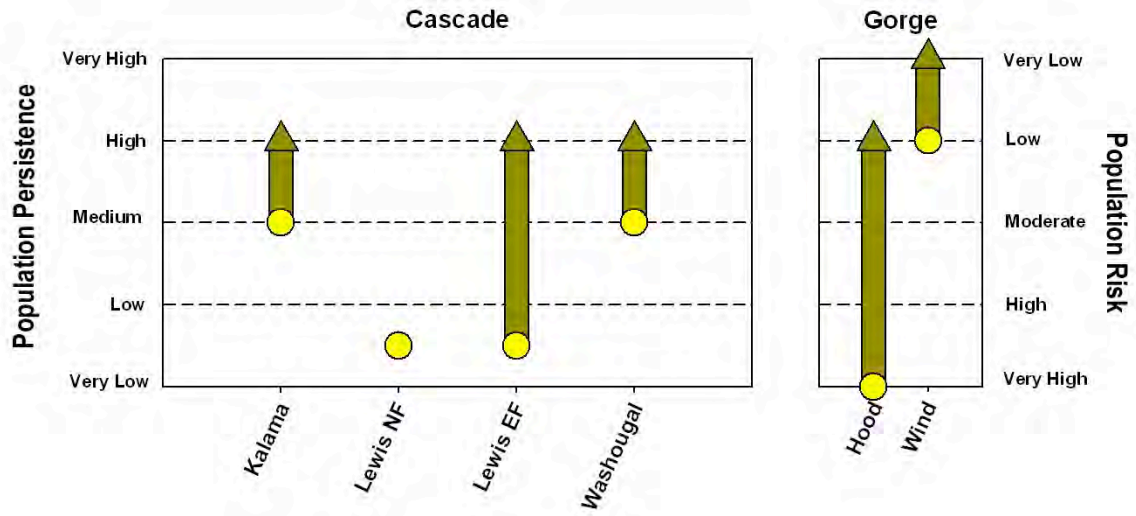


**Figure 9-6.** *Conservation Gaps for LCR Summer Steelhead Populations: Difference between Baseline and Target Status*

Source: LCFRB 2010a.

## 9.4 Limiting Factors and Threats for LCR Steelhead

Lower Columbia River steelhead are affected by a legacy of habitat degradation, harvest, hatchery production, and hydropower development that together have reduced the persistence probability of almost every population. Historically, high harvest rates contributed to population depletions, while stock transfers and straying of hatchery-origin fish reduced productivity and genetic and life history diversity. Construction of tributary and mainstem dams has constrained the spatial structure of some steelhead populations by blocking or impairing access to historical spawning areas. Over time, population abundance and productivity have been reduced through habitat alterations. Habitat alterations in the Columbia River estuary also have contributed to increased predation on steelhead juveniles. Today, widespread habitat degradation, predation, and the lingering effects of hatchery-origin fish continue to be significant limiting factors for most steelhead populations.

Tables 9-5 and 9-6 and the text that follows summarize baseline limiting factors and threats for Lower Columbia River steelhead strata based on population-specific limiting factors and threats identified in the management unit plans. In cases where conditions have changed significantly since the management unit plans' analyses of limiting factors and threats (e.g., if harvest rates have dropped or a dam is no longer present), this is noted in the text. Unless otherwise noted, NMFS agrees that the management unit plans' identification of limiting factors provide a credible hypothesis for understanding population performance and identifying management actions.

Because the individual management unit plans used somewhat different terms in identifying limiting factors, NMFS has translated those terms into standardized and more general terminology taken from a NMFS "data dictionary" of possible ecological concerns that could affect salmon and steelhead (Hamm 2012; see Section 5.4). In addition, in Tables 9-5 and 9-6, NMFS has rolled up the population-specific limiting factors (see Appendix H) to the stratum level—a process that has resulted in some loss of specificity.

In addition, each management unit plan used a different approach for identifying limiting factors and threats (see Section 5.3). One difference relevant to the crosswalk is that while the Oregon management unit plan identified primary and secondary limiting factors for each population in each threat category,[9] the Washington management unit plan categorized limiting factors in this way only for habitat-related limiting factors, and the estuary module did not use the primary and secondary terminology. For the crosswalk and this table, NMFS assigned primary and secondary status to non-habitat limiting factors for Washington populations (based on the Washington management unit plan's quantification of threat impacts and the professional judgment of Lower Columbia Fish Recovery Board's staff and consultants). It is likely that some apparent distinctions in results between Washington and Oregon populations are artifacts of differences in limiting factor assessment methodologies and not an actual difference in conditions or their effects on salmon and steelhead populations. In addition, there is not necessarily a bright line between primary and secondary limiting factor designations.

[9] In the Oregon management unit plan, primary limiting factors are those that have the greatest impact and secondary limiting factors have a lesser but still significant impact.

Nevertheless, NMFS believes that the designations are useful, particularly for looking across ESUs and populations and identifying patterns (see Chapter 4).

The management unit plans provide more detail on limiting factors and threats affecting each Lower Columbia River steelhead population, including magnitude, spatial scale, and relative impact (see LCFRB 2010a, Chapter 3 and various sections of Volume II, and ODFW 2010, pp. 129-140). For a regional perspective on limiting factors and threats that affect multiple salmon and steelhead ESUs, see Chapter 4 of this recovery plan. For a description of the data dictionary, the approach NMFS used to correlate management unit terms for limiting factors with the standardized NMFS terminology at the population scale, and the approach for rolling up from the population to the stratum scale, see Section 5.4 and Appendix H.

Management unit recovery planners in Oregon and Washington recognized that six major categories of manageable threats—tributary habitat, estuary habitat, hydropower, harvest, hatcheries, and predation—were useful as an organizing construct for grouping limiting factors, quantifying impacts on population productivity, and determining how much different categories of threats would need to be reduced to close the gap between baseline and target population status. Planners in both Washington and Oregon quantified the impacts of each of these major threat categories on population status, along with a reduction in each impact that would be consistent with achieving population target status. The results of that analysis are presented in Section 9.5 and provide a related but slightly different perspective on limiting factors. The threat reduction targets also allow actions to be scaled to achieve a specific impact reduction, and to be linked to monitoring and performance benchmarks.

**Table 9-5**

*Baseline Limiting Factors and Threats Affecting LCR Winter Steelhead: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Winter | Gorge Winter |
|---|---|---|---|---|
| **Tributary Habitat Limiting Factors** | | | | |
| Riparian Condition | Past and/or current land use practices | All | Secondary for North Fork Lewis juveniles; primary for juveniles in all other populations | Primary for Upper and Lower Gorge adults and juveniles; secondary for Hood juveniles |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Secondary for North Fork Lewis juveniles; primary for juveniles in all remaining populations | Primary for Upper and Lower Gorge adults and juveniles; secondary for Hood juveniles |
| Peripheral and Transitional Habitats: Side Channel and Wetland Conditions | Past and/or current land use practices/ transportation corridor | All | Secondary for North Fork Lewis juveniles; primary for juveniles in all other populations | Primary for Upper and Lower Gorge adults and juveniles; secondary for Hood juveniles |

**Table 9-5**

*Baseline Limiting Factors and Threats Affecting LCR Winter Steelhead: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Winter | Gorge Winter |
|---|---|---|---|---|
| Peripheral and Transitional Habitats: Floodplain Conditions | Past and/or current land use practices/ transportation corridor | All | Secondary for North Fork Lewis juveniles; primary for juveniles in all remaining populations | Primary for Upper and Lower Gorge adults and juveniles; secondary for Hood juveniles |
| Sediment Conditions | Past and/or current land use practices/ transportation corridor | All | Secondary for Clackamas, Upper Cowlitz and Cispus juveniles; secondary for Sandy adults and juveniles; primary for juveniles in all other WA populations | Secondary for Hood juveniles |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dams | A,P,D | Secondary for OR, Upper Cowlitz and Cispus juveniles; primary for juveniles in all other WA populations | Secondary for Hood juveniles |
| Water Quantity (Flow) | Dams, land use, water withdrawals for irrigation, municipal uses, and hatchery operations | All | Secondary for juveniles in all populations | Secondary for juveniles in all populations, primary for Hood juveniles (irrigation withdrawals) |
| Toxic Contaminants | Agricultural chemicals, urban and industrial practices | A,P,D | | Secondary for Hood juveniles |
| **Estuary Habitat Limiting Factors[10]** | | | | |
| Toxic Contaminants | Agricultural chemicals, urban and industrial practices | A,P,D | Secondary for juveniles in all populations | |

[10] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the DPS, the estuarine limiting factors in this table and Section 9.4.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River steelhead populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

**Table 9-5**

*Baseline Limiting Factors and Threats Affecting LCR Winter Steelhead: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Winter | Gorge Winter |
|---|---|---|---|---|
| Food[11] (Shift from macrodetrital- to microdetrital-based food web) | Dam reservoirs | All | Secondary for juveniles in all populations | |
| Peripheral and Transitional Habitats: Estuary Condition | Past and/or current land use practices, transportation corridor, mainstem dams | All | Secondary for juveniles in all populations | |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | |
| Sediment Conditions | Past and/or current land use practices/transportation corridor, dams | All | Primary for juveniles in all populations | |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dam reservoirs | A,P,D | Secondary for juveniles in all populations | |
| Water Quantity (Flow) | Columbia River mainstem dams | All | Primary for juveniles in all populations | |
| **Hydropower Limiting Factors** | | | | |
| Habitat Quantity (Access) | Bonneville Dam | All | | Secondary for Upper Gorge and Hood adults and juveniles |
| Habitat Quantity (Inundation) | Bonneville Dam | All | | Secondary for Upper Gorge and Hood juveniles[12] |
| Habitat Quantity (Access) | Tributary Dams | All | Primary for Upper Cowlitz, North Fork Lewis, Cispus, and Tilton adults and juveniles; secondary for Clackamas juveniles; secondary for Sandy adults | Secondary for Hood juveniles |
| **Harvest Limiting Factors** | | | | |
| Direct Mortality | Fisheries | A,D | Secondary for adults in all populations | |

[11] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[12] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to spring Chinook salmon as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

**Table 9-5**

*Baseline Limiting Factors and Threats Affecting LCR Winter Steelhead: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Winter | Gorge Winter |
|---|---|---|---|---|
| **Hatchery Limiting Factors** | | | | |
| Food[13] | Smolts from all Columbia Basin hatcheries competing for food and space in the estuary | All | Secondary for juveniles in all populations | |
| Population Diversity | Stray hatchery fish interbreeding with wild fish | A,P,D | Primary for Upper and Lower Cowlitz, Cispus, Tilton, Lewis, Salmon Creek, and Sandy adults; secondary for adults in all other populations | Secondary for adults in all populations |
| **Predation Limiting Factors** | | | | |
| Direct Mortality | Land use | A,P,D | Secondary for juveniles in all populations | |
| Direct Mortality | Dams | A,P,D | | Secondary for Upper Gorge and Hood adults and juveniles |

**Table 9-6**

*Baseline Limiting Factors and Threats Affecting LCR Summer Steelhead: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Summer | Gorge Summer |
|---|---|---|---|---|
| **Tributary Habitat Limiting Factors** | | | | |
| Riparian Condition | Past and/or current land use practices | All | Primary for juveniles in all populations | |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | |
| Peripheral and Transitional Habitats: Side Channel and Wetland Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | |

[13] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2013) and LCFRB (2010) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

**Table 9-6**

*Baseline Limiting Factors and Threats Affecting LCR Summer Steelhead: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Summer | Gorge Summer |
|---|---|---|---|---|
| Peripheral and Transitional Habitats: Floodplain Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for juveniles in all populations | |
| Sediment Conditions | Past and/or current land use practices/ transportation corridor | All | Primary for Kalama, Washougal, and East Fork Lewis juveniles | Primary for Wind juveniles; secondary for Hood juveniles |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dams | A,P,D | Primary for Washougal and East Fork Lewis juveniles | Primary for Wind juveniles; secondary for Hood juveniles |
| Water Quantity (Flow) | Dams, land use, irrigation, municipal, and hatchery withdrawals | All | Secondary for juveniles in all populations except North Fork Lewis | |
| Toxic Contaminants | Agricultural chemicals, urban and industrial practices | A,P,D | | Secondary for Hood juveniles |
| **Estuary Habitat Limiting Factors[14]** | | | | |
| Toxic Contaminants | Agricultural chemicals, urban and industrial practices | A,P,D | Secondary for juveniles in all populations | |
| Food[15] (Shift from macrodetrital- to microdetrital-based food web) | Dam reservoirs | All | Secondary for juveniles in all populations | |
| Peripheral and Transitional Habitats: Estuary Condition | Past and/or current land use practices/transportation corridor, mainstem dams | All | Secondary for juveniles in all populations | |
| Channel Structure and Form | Past and/or current land use practices/ transportation corridor | All | Secondary for juveniles in all populations | |

[14] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the DPS, the estuarine limiting factors in this table and Section 9.4.2 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River steelhead populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

[15] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

**Table 9-6**

*Baseline Limiting Factors and Threats Affecting LCR Summer Steelhead: Stratum-Level Summary*

| Ecological Concern | Threat(s) | VSP Parameters Affected | Cascade Summer | Gorge Summer |
|---|---|---|---|---|
| Sediment Conditions | Past and/or current land use practices/transportation corridor, dams | All | Primary for juveniles in all populations | |
| Water Quality (Temperature) | Land uses that impair riparian function/decrease streamflow, dam reservoirs | A,P,D | Secondary for juveniles in all populations | |
| Water Quantity (Flow) | Columbia River mainstem dams | All | Primary for juveniles in all populations | |
| **Hydropower Limiting Factors** | | | | |
| Habitat Quantity (Access) | Bonneville Dam | All | | Secondary for Wind and Hood adults and juveniles |
| Habitat Quantity (Inundation) | Bonneville Dam | All | | Secondary for Hood and Wind juveniles[16] |
| Habitat Quantity (Access) | Tributary dams | All | Primary for North Fork Lewis adults and juveniles | Secondary for Hood adults and juveniles |
| **Harvest Limiting Factors** | | | | |
| Direct Mortality | Fisheries | A,D | Secondary for adults in all populations | |
| **Hatchery Limiting Factors** | | | | |
| Food[17] | Smolts from all Columbia Basin hatcheries | All | Secondary for juveniles in all populations | |
| Population Diversity | Stray hatchery fish interbreeding with wild fish | A,P,D | Primary for North Fork Lewis adults; secondary for East Fork Lewis and Washougal adults | Primary for Hood adults |
| **Predation Limiting Factors** | | | | |
| Direct Mortality | Land use | A,P,D | Secondary for juveniles in all populations | Secondary for Hood juveniles |
| Direct Mortality | Dams | A,P,D | | Secondary for Hood adults and juveniles |

[16] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to spring Chinook salmon as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

[17] Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

### 9.4.1 Tributary Habitat Limiting Factors

Because steelhead are stream-type fish that typically rear in tributary reaches for a year or more, they depend heavily on tributary habitat conditions for their early survival (LCFRB 2010a). Loss and degradation of tributary habitat is one of the main limiting factors for Lower Columbia River steelhead (see Tables 9-5 and 9-6).

Impaired side channel and wetland conditions along with degraded floodplain habitat have significant negative impacts on juvenile steelhead throughout the DPS and are identified as primary limiting factors for all summer populations and all winter steelhead populations except the North Fork Lewis and Hood, where they are identified as secondary factors. In most cases, these limiting factors have resulted from extensive channelization, diking, wetland conversion, stream clearing, and gravel extraction, which have barred steelhead from historically productive habitats and simplified remaining habitats, weakening watershed processes that are essential to the maintenance of healthy ecosystems and reducing refugia and resting places. Degraded riparian conditions and channel structure and form issues are also primary limiting factors for juveniles of all summer steelhead populations and all winter populations except the North Fork Lewis and Hood, where these conditions are identified as secondary factors. A lack of large woody debris and appropriately sized gravel in the remaining accessible tributary habitat has significantly reduced the amount of suitable spawning and rearing habitat for winter steelhead.

Sediment conditions are identified as a limiting factor for juveniles in all Cascade winter populations; for Kalama, Washougal, East Fork Lewis, Wind, and Hood summer steelhead juveniles; and for juveniles from the Hood winter population. The high density of unimproved rural roads throughout the area, as well as timber harvest practices and other land use patterns on unstable slopes adjacent to riparian habitat, contributes to an abundance of fine sediment in tributary streams. The resulting excess fine sediment increases turbidity and covers spawning gravel, limiting egg development and incubation. In addition, water quality—specifically, elevated water temperature brought about through land use practices and dam reservoirs—is a primary limiting factor for juveniles in the East Fork Lewis, Washougal, and Wind summer populations and juveniles in all Washington Cascade winter populations except the Upper Cowlitz and Cispus. Water temperature is a secondary factor for juveniles from the Clackamas and Sandy winter steelhead populations and Hood summer steelhead juveniles. The influence of dams, land use, low-head hydro diversions, and irrigation withdrawals has led to water quantity issues being identified as a secondary limiting factor for all populations except the North Fork Lewis. These water quantity issues are related to altered hydrology and flow timing.

In the Cascade ecozone, land uses that have led to the conditions that limit tributary habitat productivity include forest management and timber harvest, agriculture, rural residential and urban development, and gravel extraction. A mix of private, state, and federal forest land predominates in the upper mainstem and headwater tributaries of the Cascade subbasins, while the lower mainstem and tributary reaches of most subbasins are characterized by agricultural and rural residential land use, with some urban development, especially in the Salmon Creek and Clackamas subbasins.

A unique issue in the Cascade stratum is legacy effects in the Toutle subbasin of the 1980 Mount St. Helens eruption. The North Fork Toutle in particular was heavily affected by sedimentation from the eruption. A sediment retention structure was constructed on the North Fork Toutle in an attempt to prevent continued severe sedimentation of stream channels and associated flood conveyance, transportation, and habitat degradation problems. The structure currently blocks access to as many as 50 miles of habitat for anadromous fish. Although fish are transported around the structure via a trap and haul system, it remains a source of chronic fine sediment to the lower river; this reduces habitat quality and has interfered with fish collection at its base.

In the Gorge ecozone, habitat limiting factors are generally the same as those described for the DPS as a whole, with some exceptions. For example, sediment conditions and water quality were not identified as limiting factors for the Upper and Lower Gorge winter steelhead populations. In addition, the primary cause of impaired side channel, wetland, and floodplain conditions for these populations is transportation corridor development. Highway and transportation corridors run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes. For the Hood winter steelhead population, all tributary habitat limiting factors were secondary with the exception of reduced instream flow caused by irrigation withdrawals, which was identified as a primary limiting factor. For the Hood summer population, riparian conditions and impaired side channel, wetland, and floodplain habitat were identified as primary tributary limiting factors.

Also unique to the Hood populations, both winter and summer, was the identification of organophosphates, insecticides, and other agricultural chemicals as a secondary limiting factor for juveniles. In addition, inundation of historical habitat by Bonneville Reservoir is identified as a secondary limiting factor for Upper Gorge winter steelhead and both winter and summer Hood populations.

### 9.4.2 Estuary Habitat Limiting Factors[18]

As stream-type fish, steelhead spend less time in the Columbia River estuary and plume than do ocean-type salmon such as fall Chinook, yet estuary habitat conditions nevertheless play an important role in the survival of steelhead juveniles, particularly those displaying less dominant life history strategies. Water quantity issues related to altered hydrology and flow timing are identified as a primary limiting factor for all populations, as is impaired sediment and sand routing; these limiting factors are associated with hydroregulation at large storage reservoirs in the interior of the

[18] The Washington and Oregon management unit plans both relied on the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) for information on estuary limiting factors, but there were some differences in how the plans translated the information into limiting factors experienced at the population level. The estuary module does not designate limiting factors as primary or secondary; instead, it ranks them in terms of assumed impact on ocean- and stream-type salmonids. Because the Oregon management unit plan integrated the module information with more specificity than did the Washington management unit plan, and because NMFS assumes that estuarine limiting factors affect all populations equally within the DPS, the estuarine limiting factors in this section and Tables 9-5 and 9-6 reflect the determinations in the Oregon management unit plan, applied to all Lower Columbia River steelhead populations, unless otherwise noted. As with other limiting factors, the designations of estuarine limiting factors as primary or secondary reflect working hypotheses that will need to be tested (and possibly revised) through adaptive management.

Columbia Basin, and, in the case of sediment issues, land uses both past and present. Much of the land surrounding the Columbia River estuary is in agricultural or rural residential use and has been extensively modified via dikes, levees, bank stabilization, and tide gates. Altered hydrology and sediment routing influence habitat-forming processes, the quantity and accessibility of habitats such as side channels and wetlands, the dynamics of the Columbia River plume, and the estuarine food web. Channel structure issues, in the form of reduced habitat complexity and diversity, also are a primary limiting factor for juveniles from all populations. Again, simplification of channel structure is related to conversion of land to other uses—agricultural, rural residential, and as a transportation corridor.

Lack of access to peripheral and transitional habitats, such as side channels and wetlands is a secondary limiting factor for all populations, with access being impaired by the land uses—including the transportation corridor—and by flow alterations caused by mainstem dams. Other secondary limiting factors in the estuary that affect all steelhead populations are exposure to toxic contaminants (from urban, industrial, and agricultural sources) and elevated late summer and fall water temperatures, which are related to (1) land use practices that impair riparian function or decrease streamflow, and (2) large hydropower reservoirs.[19] Altered food web dynamics involving a transition from a macrodetrital-based food web to a microdetrital-based food web also are considered a secondary limiting factor for all populations.[20] These changes in the estuarine food web are caused primarily by increased microdetrital inputs from hydropower reservoirs and the loss of wetland habitats through diking and filling.

### 9.4.3 Hydropower Limiting Factors

The severity of dam-related impacts on winter steelhead populations varies throughout the DPS. Flow management operations at large storage reservoirs in the interior of the Columbia Basin (Grand Coulee, Dworshak, etc.) affect all juvenile Lower Columbia River steelhead in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat-forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and estuarine food web (see Section 9.4.2).[21] Moreover, the large reservoirs associated with mainstem dams contribute to elevated water temperatures downstream in late summer and fall. Although the management unit plans identified temperature impacts of the hydropower system as a secondary limiting factor for all juvenile steelhead, migration of juvenile steelhead occurs primarily in April through June (Dawley et al. 1986, McCabe et al. 1986, Roegner et al. 2004, Bottom et al. 2008, cited in Figure 2.2 of Carter et al. 2009), when elevated

[19] Although the management unit plans identified temperature impacts as a secondary limiting factor for juveniles in all populations, the timing of juvenile steelhead migration raises questions about the significance of this limiting factor; see Section 9.4.3.

[20] Although the Oregon management unit plan lists food web shifts as a primary limiting factor in the estuary, NMFS and the management unit planners agreed to consider such shifts secondary in this recovery plan to more closely reflect conclusions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a). The extent to which food web shifts limit salmonid survival in the estuary is unclear.

[21] It is likely that flow impacts of the hydropower system affect the Lower Columbia River steelhead DPS more through changes in habitat-forming processes (including impacts to the plume) and food web impacts than through changes in migratory travel time.

mainstem temperatures are unlikely to be having a significant impact. The impacts of Bonneville Dam on passage and habitat quantity have been identified as a secondary limiting factor for Upper Gorge winter steelhead, Wind summer steelhead, and both populations of Hood steelhead.[22]

The effects of tributary dams vary among steelhead populations. In the Cascade winter steelhead stratum, tributary hydropower development is a primary limiting factor for adults and juveniles in the Upper Cowlitz, Cispus, and North Fork Lewis populations, which historically were among the most productive winter steelhead populations, and for the Tilton population; access to significant amounts of historical habitat in these river systems has been blocked by tributary dams, which also have had adverse impacts on downstream habitat through reduced gravel recruitment and other effects. Tributary hydropower issues related to upstream passage of adult winter steelhead past the Bull Run water system dams in the Sandy subbasin and downstream passage of juvenile winter steelhead through the PGE Clackamas River Project were identified as secondary limiting factors. There are no tributary hydropower facilities in the Coweeman, Toutle, Kalama, Salmon Creek, or Washougal subbasins.[23]

In the Cascade summer steelhead stratum, impaired habitat access and passage has been identified as a primary limiting factor for North Fork Lewis summer steelhead; tributary dams have blocked access to or inundated about 50 percent of the historical habitat for that population (LCFRB 2010a). In addition, tributary dams have adverse effects on downstream habitat through reduced gravel recruitment and other impacts. There are no tributary hydropower facilities in the Kalama and Washougal subbasins.

In the Gorge winter steelhead stratum, impaired adult passage is considered a secondary limiting factor for the Hood River population because of Laurence Lake Dam and Powerdale Dam (removed in 2010). The impacts of Bonneville Dam on adult and juvenile passage are identified as a secondary factor for both the Upper Gorge and Hood winter steelhead populations. Upstream passage to potential spawning grounds is limited by Bonneville Dam, and inundation of historical habitat has reduced habitat quantity for juveniles.

In the Gorge summer steelhead stratum, Powerdale Dam on the Hood River hindered access of adult steelhead to historical spawning areas until its removal in 2010. Inundation from the Bonneville Dam and the concomitant loss of historical riparian ecosystems has also reduced habitat quality for juvenile summer steelhead in the Hood River population.

### 9.4.4 Harvest Limiting Factors

Harvest-related mortality is identified as a secondary limiting factor for all populations within the DPS. Currently, harvest-related mortality on steelhead is limited to incidental mortality in Columbia River mainstem commercial gillnet fisheries, incidental mortality

[22] The exact extent to which Bonneville Dam inundated habitats for any species is unknown. Some biologists have hypothesized impacts to steelhead as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon.

[23] However, the North Fork Toutle sediment retention structure currently blocks access to as many as 50 miles of habitat for anadromous fish.

in tributary recreational fisheries, and small levels of directed harvest in tribal fisheries above Bonneville Dam in Zone 6. Before the mid-1970s, harvest levels on natural-origin steelhead regularly exceeded 70 percent. However, implementation of mark-selective fisheries for hatchery steelhead has reduced recent impacts to 10 percent or less for most populations. Summer steelhead populations originating above Bonneville Dam are subject to somewhat higher rates—on the order of 15 percent or less— as a result of the combined effects tribal and non-tribal fisheries. Although the management unit plans identify steelhead harvest as a limiting factor, they also determine that the significant reduction in the harvest of steelhead over the last 20 or 30 years has resulted in harvest levels that appear to be consistent with achieving recovery objectives (ODFW 2010, LCFRB 2010a).

### 9.4.5 Hatchery-Related Limiting Factors

More than 2 million winter steelhead and 1.4 million summer steelhead were released from Lower Columbia River hatchery programs in 2008 (ODFW 2010). Many Lower Columbia River steelhead populations have large proportions of hatchery-origin spawners. Population-level effects resulting from stray hatchery fish interbreeding with natural-origin fish are identified as a primary limiting factor for the Upper and Lower Cowlitz, Cispus, Tilton, Lewis, Salmon Creek, and Sandy winter populations and the North Fork Lewis and Hood summer populations, and as a secondary limiting factor for the East Fork Lewis and Washougal summer populations and all other winter populations.[24] Hatchery straying, combined with past stock transfers, is believed to have reduced genetic diversity within and among Lower Columbia River steelhead populations. Productivity likewise has declined as a result of the influence of hatchery-origin fish. High proportions of hatchery-origin spawners are sometimes intentional, however, because hatchery fish are being used to reintroduce steelhead where they have been extirpated or nearly so (e.g., in the Cowlitz, and Lewis subbasins). In identifying hatchery-related limiting factors, the management unit plans evaluated only negative impacts of hatchery fish on productivity of natural fish and not the positive demographic benefits that such reintroduction programs can provide in the short term.

Some scientists suspect that closely spaced releases of hatchery fish from all Columbia Basin hatcheries may lead to increased competition with natural-origin fish for food and habitat space in the estuary. NMFS (2011a) and LCFRB (2010a) identified competition for food and space among hatchery and natural-origin juveniles in the estuary as a critical uncertainty. ODFW (2010) acknowledged that uncertainty but listed competition for food and space as a secondary limiting factor for juveniles of all populations. The NMFS Northwest Region and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon and steelhead in freshwater, estuarine, and nearshore ocean habitats.

[24] The nature and extent of risk to natural populations posed by hatchery programs affecting these populations will be the focus of future ESA section 7 consultations.

### 9.4.6 Predation

Direct mortality from predation is a secondary limiting factor that affects all Lower Columbia River steelhead populations. Anthropogenic changes to habitat structure have led to increased predation by Caspian terns, double-crested cormorants, and various other seabird species in the Columbia River estuary and plume. Steelhead spawning above Bonneville Dam also are subject to predation by non-salmonid fish (primarily pikeminnows above and below the dam but also walleye and smallmouth bass in the reservoir). Winter steelhead spawning above Bonneville Dam are also subject to predation by marine mammals (primarily sea lions) at Bonneville Dam.

## 9.5 Baseline Threat Impacts and Threat Reduction Targets

Table 9-7 shows the estimated impact on each Lower Columbia River steelhead population of potentially manageable threats, organized into six threat categories: tributary habitat degradation, estuary habitat degradation, hydropower, harvest, hatcheries, and predation. Both baseline and target impacts are shown, with the targets representing levels that would be consistent with long-term recovery goals. Impact values indicate the percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. The value associated with any particular threat category can be interpreted as the percent reduction in abundance and productivity from historical conditions if that threat category were the only one affecting the population. The table also shows the overall percentage improvement that is needed to achieve the target impacts and corresponding population status.[25] These cumulative values across all threat categories (both baseline and target) are multiplicative rather than additive. Both the Oregon and Washington management unit plans use cumulative survivals across threat categories to illustrate the overall level of improvement needed. Each plan assumes that there is a direct proportional relationship between the projected changes in cumulative survival and the required changes in natural-origin spawner abundance and productivity. For populations where the survival improvement needed is larger than 500 percent, Table 9-7 does not report the exact value, in part because the value is highly uncertain.[26]

As an example, the baseline status of the Clackamas winter steelhead population has been severely reduced by the combined effects of multiple threats. The cumulative reduction in status was estimated at 81.8 percent from the multiplicative impacts of multiple threats acting across the salmon life cycle. Thus, current status is just 18.2 percent of the historical potential with no human impact. Tributary habitat and hatchery

[25] The percentage of survival improvement needed is the percentage change in net impacts, is derived from information in the Washington and Oregon management unit plans, and is calculated as follows: $[(1-\text{Cumulative}_{\text{Target}})-(1-\text{Cumulative}_{\text{Baseline}})]/[1-\text{Cumulative}_{\text{Baseline}}] \times 100$. These values generally correspond to population improvement targets identified for Washington populations in LCFRB (2010a). Comparable numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts.

[26] For some populations—many of them small—the survival improvement needed is very large and highly uncertain because various other factors also are uncertain (i.e., the population's baseline persistence probability, the exact degree of impact of human activities on tributary habitat, and whether the population's response to reductions in impacts will be linear). In addition, very small populations do not necessarily follow predictable patterns in their response to changing conditions.

impacts are the largest, accounting independently for reductions of 65 and 23 percent, respectively, in population productivity, with corresponding reductions in abundance, spatial structure, and diversity. The Oregon management unit plan identifies a recovery strategy for this population that involves significant reductions in the impact of habitat and hatcheries and smaller reductions in the impacts of estuarine habitat and predation. For instance, the plan targets tributary habitat impacts to be reduced from the estimated baseline level of 65 percent to 24 percent (i.e., an approximately 117 percent improvement relative to baseline conditions). With the targeted reductions in individual impacts, the cumulative effect of all impacts would drop from 81.8 percent at baseline to 50 percent at the target status. This change would translate into a 170 percent improvement in survival relative to the baseline. Although the population would still be experiencing abundance and productivity that are 74.7 percent lower than historical conditions, the extinction risk at this mortality level would be estimated sufficient to meet the targets for this plan.

Oregon and Washington recovery planners used somewhat different definitions or methods to quantify the estimated impacts of anthropogenic threats. Baseline impacts for Washington populations reflect conditions prevalent at the time of ESA listing (circa 1999), while the baseline impacts for Oregon populations reflect conditions through 2004. Dam impacts for Washington populations reflect passage mortality, habitat loss caused by inundation, and loss of access to historical production areas; for Oregon populations, the estimates in the "Dams" column of Table 9-7 reflect direct upstream and downstream passage mortality only, with other dam impacts accounted for in the habitat and predation threat categories. Hatchery impacts for Washington populations were limited to not more than 50 percent per population, in accordance with Hatchery Scientific Review Group (HSRG) assessments of the potential for genetic effects (Hatchery Scientific Review Group 2009); Oregon recovery planners estimated that hatchery impacts were equivalent to the rates at which hatchery fish were found on natural spawning grounds, based on analyzed relationships and reflecting a concern for both genetic and ecological effects. Washington recovery planners derived estimates of impacts to tributary habitat using the Ecosystem Diagnosis and Treatment (EDT) model. Oregon recovery planners estimated the mortality associated with estuary habitat degradation, hydropower, harvest, hatcheries, and predation and assigned all remaining mortality (relative to the difference between the current modeled abundance and estimated historical abundance) to tributary habitat. In general, the tributary habitat values in Table 9-7 have the highest degree of uncertainty relative to the other threat categories and, for Oregon populations, may include causes of mortality associated with the other threat categories but not directly captured in those mortality estimates. (See Section 5.5 for more on the methodologies used to estimate baseline impacts.)

Estimates of threat impacts are useful in showing the relative magnitude of impacts on each population. Given the differences in methodologies, some values in Table 9-7 for Oregon and Washington populations are not necessarily directly comparable. Thus, values for Oregon populations are most directly comparable to those for other Oregon populations, and values for Washington populations are most directly comparable to those for other Washington populations. Regardless of differences in specific threat impact definitions and methods, the net effect of changes from all threats is useful in understanding the magnitude of population improvement needed to achieve the target population status.

The target impacts represent one of several possible combinations of threat reductions that could conceivably close the conservation gap and lead to a population achieving its target status. The particular threat reductions shown in Table 9-7 reflect policy decisions and the methodologies and assumptions used by the different recovery planning teams. (For a description of how target impacts were developed, see Section 5.6.) In estimating impacts, management unit recovery planners evaluated each threat category independently (i.e., values in the table reflect the mortality of steelhead exposed to that particular category of threats, whether or not they are exposed to threats in other categories). The estimates of baseline threat impacts have high levels of uncertainty and in many cases should be considered working hypotheses that are testable as part of recovery plan implementation. Despite this uncertainty, it is the expert judgment of NMFS and management unit scientists that, based on the best available information at this time, the estimates of baseline threat impacts provide a reasonable estimate of the relative magnitude of different sources of anthropogenic mortality and serve as an adequate basis for designing initial recovery actions.[27] As more and better information is collected, it will be applied to recovery efforts in an adaptive management framework.

As shown in Table 9-7, loss and degradation of tributary habitat, hatchery effects, and predation are pervasive threats that affect most steelhead populations. However, expected threat reductions vary by population.

In the Cascade ecozone, the Upper Cowlitz, Cispus, Tilton, and North Fork Lewis winter populations and the East Fork Lewis summer population are targeted for the largest improvements, with sizeable reductions needed in all or most threat categories, including predation. For the Upper Cowlitz, Cispus, Tilton, and North Fork Lewis winter populations, the greatest gains in persistence probability are expected to be achieved by reestablishing natural populations above tributary dams; however, reductions in hatchery- and tributary habitat-related threats are also targeted to contribute significantly to gains in persistence probability. For the East Fork Lewis summer population, improvements in tributary habitat are projected to provide the greatest benefit. All of these populations are designated primary except the Tilton and North Fork Lewis winter populations, which are designated as contributing.

Other Cascade populations targeted for large threat reductions are the Clackamas and Sandy winter steelhead populations. For Sandy winter steelhead, the most significant threat reductions are targeted to be achieved through reductions in hatchery-related threats.[28] For Clackamas winter steelhead, sizeable reductions in both hatchery- and tributary habitat-related threats are called for.[29] The threat reductions needed to achieve targets for other primary and contributing populations within the Cascade strata are relatively small, with improvements in tributary habitat figuring most prominently. This is the case for the Lower Cowlitz, North and South Fork Toutle, Coweeman, Kalama,

[27] As implementation proceeds, research, monitoring, and evaluation and adaptive management will be key in helping to refine scientific understanding of the impact of threats on population persistence and of the extent to which management actions are reducing threats.

[28] The Oregon management unit plan states that, because of fairly recent changes in the management of the hatchery steelhead program, current stray rates in the Sandy winter steelhead population already are lower than the 10 percent called for delisting (ODFW 2010).

[29] However, the Oregon management unit plan describes the targeted level of tributary habitat improvements for the Clackamas winter steelhead population as infeasible (see ODFW 2010).

East Fork Lewis, and Washougal winter populations and the Kalama and Washougal summer populations. For the Kalama summer steelhead population, Table 9-7 does not show threat reductions because the baseline abundance and productivity of the population are high; however, improvements in diversity will be needed in the Kalama summer population to meet recovery objectives.

The Salmon Creek winter and North Fork Lewis summer steelhead populations are not targeted for threat reductions, although they are expected to benefit from actions to reduce threats to other species and populations. These populations are designated as stabilizing because of habitat degradation in the highly urbanized Salmon Creek subbasin and because access to most of the North Fork summer population's historical spawning habitat has been blocked by Merwin Dam.

In the Gorge strata, all populations are designated as primary except the Upper Gorge winter population, which is considered contributing. For the Lower and Upper Gorge winter populations, target status is targeted to be achieved mostly by reducing tributary habitat-related threats, especially in Oregon. For the Hood winter population, no tributary habitat threat reductions are called for. Instead, the greatest gains in persistence probability are targeted from reductions in hatchery- and hydropower-related threats. The Hood summer steelhead population is targeted for significant reductions in multiple threat categories, with particularly large reductions in tributary habitat- and hydropower-related threats and a complete elimination of hatchery threats (summer steelhead will no longer be released in the Hood subbasin).[30] For the Wind summer steelhead population, Table 9-7 does not show threat reductions because the baseline abundance and productivity of the population are very high; however, improvements in diversity will be needed in the Wind summer population to meet recovery objectives.

With harvest impacts on natural-origin winter steelhead having dropped substantially from historical highs, further reductions in harvest impacts do not figure prominently in the threat reduction scenarios for most steelhead populations. The recovery strategy involves continued management of fisheries to limit impacts to baseline levels.

Threat reductions associated with estuary habitat improvements are needed for recovery and will benefit every steelhead population; however, net reductions in this threat category are smaller than those for tributary habitat-related threats, hatcheries, predation, and, in some cases, hydropower and harvest because for most populations the impacts of estuarine habitat-related threats are less.

More information on threat reductions, including methodologies used to determine baseline and target impacts, is available in the management unit plans (ODFW 2010, pp. 151-168 and 195-200; LCFRB 2010a, pp. 4-30 through 4-33 and 6-65 through 6-70).

[30] The targeted level of tributary habitat improvements for the Hood summer steelhead population is described in the Oregon management unit plan as infeasible (see ODFW 2010).

## Table 9-7

*Impacts of Potentially Manageable Impacts of Threats and Impact Reduction Targets Consistent with Recovery of LCR Steelhead Populations*

| Population | Impacts at Baseline[31] | | | | | | | Impacts at Target | | | | | | | % Survival Improve-ment Needed[32] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[33] | Est[34] | Dams[35] | Har[36] | Hat[37] | Pred[38] | Cumul-ative[39] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumul-ative | |
| **Cascade Summer** | | | | | | | | | | | | | | | |
| Kalama (WA) | 0.43 | 0.15 | 0.00 | 0.10 | 0.01 | 0.24 | 0.6719 | 0.43 | 0.15 | 0.00 | 0.10 | 0.01 | 0.24 | 0.6719 | 0 |
| NF Lewis (WA) | 0.40 | 0.15 | 0.50 | 0.10 | 0.47 | 0.24 | 0.9076 | 0.40 | 0.15 | 0.50 | 0.10 | 0.47 | 0.24 | 0.9076 | 0 |
| EF Lewis (WA) | 0.70 | 0.15 | 0.00 | 0.10 | 0.26 | 0.24 | 0.8709 | 0.35 | 0.08 | 0.00 | 0.05 | 0.13 | 0.12 | 0.5651 | >500 |

[31] Impact figures represent a percentage reduction in abundance and productivity that is attributable to human activities related to a particular threat category. Methods used to estimate impacts differ for Oregon and Washington populations. For example, baseline impacts reflect conditions circa 1999 for Washington populations and through 2004 for Oregon populations. Given the methodological differences, impact figures are not necessarily directly comparable. See Sections 5.5 and 5.6 for more on methodologies.

[32] Survival improvements indicate the percentage improvement (rounded to the nearest 10) in population survival needed to achieve target impacts and are derived from the cumulative values (baseline and target). For most populations this was calculated using the following equation: $[(1\text{-Cumulative}_{Target})\text{-}(1\text{-Cumulative}_{Baseline})]/[1\text{-Cumulative}_{Baseline}] \times 100$. For the East Fork Lewis population , this equation yields a different result than that reported in LCFRB (2010a) because, for populations that have a very low probability of persistence and require very large improvements, the Washington management unit plan limited threat-specific reductions to 50 percent of the current impact as interim targets until the population response to improvements can be accurately gauged. For the East Fork Lewis, the numbers reported in this table are consistent with LCFRB (2010a) rather than with the aforementioned equation. In addition, these cumulative impact numbers are not explicitly reported in ODFW (2010) but are implicit in the modeling approach that Oregon recovery planners used to derive target impacts. For populations where the survival improvement needed is larger than 500 percent, this table does not report the exact value, for the reasons explained in Section 9.5.

[33] Reduction in tributary habitat production potential relative to historical conditions. Oregon and Washington used different methods to estimate historical abundance. Oregon's approach, which incorporates safety margins and includes causes of mortality that are not captured in the other five threat categories, tends to indicate a higher potential impact from tributary habitat loss and degradation than does Washington's.

[34] Reduction in juvenile survival in the Columbia River estuary as a result of habitat changes (relative to historical conditions); excludes predation.

[35] Reflects passage mortality, habitat loss caused by inundation, and loss of access to historical production areas for Washington populations; for Oregon populations, dam impacts reflect direct passage mortality only.

[36] Includes direct and indirect mortality.

[37] Reflects only the negative impacts of hatchery-origin fish, such as high pHOS and low PNI (proportion of natural influence), not the benefits of conservation hatchery programs.

[38] Includes the aggregate predation rate in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals, Caspian terns, and cormorants.

[39] Cumulative values (both baseline and target) are multiplicative rather than additive and are equal to $(1\text{-}[(1\text{-}M_{thab})(1\text{-}M_{est})(1\text{-}M_{dams})(1\text{-}M_{harv})(1\text{-}M_{hatch})(1\text{-}M_{pred})])$. Minor differences from numbers in ODFW 2010 and LCFRB 2010a are due to rounding.

## Table 9-7

*Impacts of Potentially Manageable Impacts of Threats and Impact Reduction Targets Consistent with Recovery of LCR Steelhead Populations*

| Population | Impacts at Baseline[31] | | | | | | | Impacts at Target | | | | | | | % Survival Improvement Needed[32] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[33] | Est[34] | Dams[35] | Har[36] | Hat[37] | Pred[38] | Cumulative[39] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumulative | |
| Washougal (WA) | 0.40 | 0.15 | 0.00 | 0.10 | 0.30 | 0.24 | 0.7558 | 0.32 | 0.12 | 0.00 | 0.08 | 0.24 | 0.19 | 0.6611 | 40 |
| **Gorge Summer** | | | | | | | | | | | | | | | |
| Wind (WA) | 0.50 | 0.14 | 0.11 | 0.17 | 0.01 | 0.27 | 0.7704 | 0.50 | 0.14 | 0.11 | 0.17 | 0.01 | 0.27 | 0.7704 | 0 |
| Hood (OR)[40] | 0.95 | 0.07 | 0.36 | 0.15 | 0.53 | 0.15 | 0.9899 | 0.14 | 0.07 | 0.16 | 0.15 | 0.00 | 0.08 | 0.4746 | >500 |
| **Cascade Winter** | | | | | | | | | | | | | | | |
| Lower Cowlitz (WA) | 0.70 | 0.15 | 0.00 | 0.10 | 0.49 | 0.24 | 0.9110 | 0.69 | 0.15 | 0.00 | 0.10 | 0.48 | 0.23 | 0.9053 | 10 |
| Upper Cowlitz (WA) | 0.40 | 0.15 | 1.00 | 0.10 | 0.49 | 0.24 | 1.00 | 0.20 | 0.08 | 0.50 | 0.05 | 0.25 | 0.12 | 0.7693 | >500[41] |
| Cispus (WA) | 0.60 | 0.15 | 1.00 | 0.10 | 0.49 | 0.24 | 1.00 | 0.30 | 0.08 | 0.50 | 0.05 | 0.25 | 0.12 | 0.7981 | >500 |
| Tilton (WA) | 0.90 | 0.15 | 1.00 | 0.10 | 0.49 | 0.24 | 1.00 | 0.45 | 0.08 | 0.50 | 0.05 | 0.25 | 0.12 | 0.8414 | >500 |
| SF Toutle (WA) | 0.80 | 0.15 | 0.00 | 0.10 | 0.24 | 0.24 | 0.9116 | 0.74 | 0.14 | 0.00 | 0.09 | 0.22 | 0.22 | 0.8762 | 40 |
| NF Toutle (WA) | 0.80 | 0.15 | 0.00 | 0.10 | 0.33 | 0.24 | 0.9221 | 0.64 | 0.12 | 0.00 | 0.08 | 0.26 | 0.19 | 0.8253 | 120 |
| Coweeman (WA) | 0.50 | 0.15 | 0.00 | 0.10 | 0.12 | 0.24 | 0.7442 | 0.43 | 0.13 | 0.00 | 0.09 | 0.10 | 0.20 | 0.6751 | 30 |
| Kalama (WA) | 0.50 | 0.15 | 0.00 | 0.10 | 0.02 | 0.24 | 0.7151 | 0.37 | 0.11 | 0.00 | 0.07 | 0.02 | 0.18 | 0.5810 | 50 |
| NF Lewis (WA) | 0.10 | 0.15 | 0.92 | 0.10 | 0.49 | 0.24 | 0.9787 | 0.05 | 0.08 | 0.46 | 0.05 | 0.25 | 0.12 | 0.7041 | >500 |
| EF Lewis (WA) | 0.50 | 0.15 | 0.00 | 0.10 | 0.48 | 0.24 | 0.8488 | 0.45 | 0.14 | 0.00 | 0.09 | 0.44 | 0.22 | 0.8120 | 20 |
| Salmon Creek (WA) | 0.80 | 0.15 | 0.00 | 0.10 | 0.50 | 0.24 | 0.9419 | 0.80 | 0.15 | 0.00 | 0.10 | 0.50 | 0.24 | 0.9419 | 0 |

[40] Oregon's analysis indicates a low probability of meeting the delisting objective of high viability persistence probability for this population.

[41] The Upper Cowlitz, Cispus, and Tilton populations require improvements in every threat category. However, given that hydropower impacts are 100 percent for these populations, they will not benefit from improvements in the other threat categories until some degree of passage is restored. Although passage improvements alone will not lead to recovery, how successful passage improvements are will greatly influence how much improvement is needed in the other threat categories. In addition the formula for percent survival improvement for these populations was modified to account for the 100 percent hydropower impacts (i.e., to avoid having to divide by zero).

## Table 9-7

*Impacts of Potentially Manageable Impacts of Threats and Impact Reduction Targets Consistent with Recovery of LCR Steelhead Populations*

| Population | Impacts at Baseline[31] | | | | | | | Impacts at Target | | | | | | | % Survival Improve-ment Needed[32] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. Hab[33] | Est[34] | Dams[35] | Har[36] | Hat[37] | Pred[38] | Cumul-ative[39] | T. Hab | Est | Dams | Harv | Hat | Pred | Cumul-ative | |
| Clackamas (OR)[42] | 0.65 | 0.10 | 0.05 | 0.10 | 0.23 | 0.12 | 0.8175 | 0.24 | 0.08 | 0.05 | 0.10 | 0.10 | 0.07 | 0.4996 | 170 |
| Sandy (OR) | 0.82 | 0.10 | 0.04 | 0.10 | 0.52 | 0.12 | 0.9409 | 0.81 | 0.08 | 0.00 | 0.10 | 0.10 | 0.07 | 0.8683 | 120 |
| Washougal (WA) | 0.50 | 0.15 | 0.00 | 0.10 | 0.08 | 0.24 | 0.7326 | 0.46 | 0.14 | 0.00 | 0.09 | 0.08 | 0.22 | 0.6967 | 10 |
| **Gorge Winter** | | | | | | | | | | | | | | | |
| L. Gorge —WA portion | 0.60 | 0.15 | 0.00 | 0.10 | 0.01 | 0.22 | 0.7637 | 0.48 | 0.12 | 0.00 | 0.08 | 0.00 | 0.18 | 0.6548 | 50 |
| L. Gorge—OR portion | 0.60 | 0.10 | 0.00 | 0.10 | 0.10 | 0.12 | 0.7434 | 0.40 | 0.08 | 0.00 | 0.10 | 0.10 | 0.07 | 0.5842 | 60 |
| U. Gorge—WA portion | 0.60 | 0.14 | 0.11 | 0.10 | 0.01 | 0.30 | 0.8090 | 0.60 | 0.14 | 0.11 | 0.10 | 0.01 | 0.30 | 0.8090 | 0 |
| U. Gorge—OR portion | 0.51 | 0.07 | 0.16 | 0.15 | 0.10 | 0.16 | 0.7540 | 0.30 | 0.07 | 0.16 | 0.15 | 0.10 | 0.10 | 0.6235 | 50 |
| Hood (OR) | -0.01 | 0.07 | 0.36 | 0.15 | 0.30 | 0.16 | 0.6995 | -0.01 | 0.07 | 0.16 | 0.15 | 0.10 | 0.10 | 0.4675 | 80 |

[42] Oregon's analysis indicates a low probability of meeting the delisting objective of high viability persistence probability for this population.

## 9.6 DPS Recovery Strategy for LCR Steelhead

This section describes the recovery strategy for Lower Columbia River steelhead. A general summary of the DPS-level strategy is presented first. This is followed by subsections on each of the threat categories and critical uncertainties that pertain to the strategy. Where appropriate, stratum-specific strategies are described for each threat category.

### 9.6.1 Strategy Summary

The recovery strategy for the Lower Columbia River steelhead DPS is aimed at restoring the Cascade and Gorge winter and summer strata to a high probability of persistence.[43] Although the strategy involves threat reductions in all categories, the most crucial elements are as follows:

1. Protect favorable tributary habitat and restore degraded but potentially productive habitat, especially in subbasins where large improvements in population abundance and productivity are needed to achieve recovery goals. This is the case in the Upper Cowlitz, Cispus, North Fork Toutle, Kalama, and Sandy subbasins for winter steelhead and in the East Fork Lewis and Hood subbasins for summer steelhead.

2. Protect and improve the South Fork Toutle, East Fork Lewis, Clackamas, and Hood winter steelhead populations, which currently are the best-performing winter populations, to a high probability of persistence. This will be accomplished through population-specific combinations of threat reductions, to include protection and restoration of tributary habitat (crucial for all except the Hood population), reductions in pHOS, and—for the Hood population—removal of Powerdale Dam (this was completed in 2010).

3. Significantly reduce hatchery impacts on the Hood summer steelhead population[44] and, to a lesser degree, on many other populations, especially the Upper Cowlitz, Cispus, Tilton, North Fork Lewis, and Clackamas winter populations and the East Fork summer population. Continue to limit hatchery impacts on the Kalama and Wind summer steelhead populations to improve population diversity. (The baseline abundance and productivity of these two populations are high and very high, respectively.)

4. Reestablish naturally spawning winter steelhead populations above tributary dams in the Cowlitz system (Upper Cowlitz and Cispus populations) and improve the status of the Tilton winter steelhead population through hatchery

[43] Steelhead populations in the Coast ecozone are part of the Southwest Washington steelhead DPS and are not listed under the federal ESA; thus, they are not addressed in this recovery plan.

[44] The Sandy winter steelhead population was also targeted for a significant reduction in hatchery impacts (i.e., 80 percent). However, the Oregon management unit plan states that, because of fairly recent changes in the management of the hatchery steelhead program, current stray rates in the Sandy winter steelhead population already are lower than the 10 percent called for in the threat reduction targets (ODFW 2010 p. 196).

reintroductions and comprehensive threat reductions; reintroduce winter steelhead above dams on the North Fork Lewis River.

5. Reduce predation by birds, non-salmonid fish, and marine mammals.

If the DPS is to achieve recovery, improvements are needed in the persistence probability of most populations, and very large improvements are needed in the status of some populations (the Upper Cowlitz, Cispus, North Fork Toutle, Kalama, and Sandy winter populations and the East Fork Lewis and Hood summer populations). (See Table 9-4 for the target status for each steelhead population and Figures 9-5 and 9-6 for the gaps between baseline and target status.)

The recovery strategy for Lower Columbia River steelhead is a long-term, "all-H" approach in which plan implementers begin work on all of the elements described above immediately and implement actions associated with each of the six threat categories simultaneously.[45] As part of a series of 3- to 5-year implementation schedules, management unit planners will work with NMFS staff to prioritize individual actions within each threat category, rather than across threat categories (see Chapter 11 for more on implementation). Recovery will require improvements in every threat category, even those improvements in Table 9-7 that are relatively small. Substantial actions are needed to improve tributary habitat, reduce the effects of hatcheries on natural populations, manage predation, and, for some populations, address hydropower passage issues. Without improvements in all of these threat categories, the full benefits of actions in any individual sector, such as improved passage at tributary dams, are unlikely to be realized and the expected threat reductions will not be achieved. Recovery also will require contributions from estuary habitat actions; however, for stream-type fish such as steelhead, these gains are expected to be less than those from coordinated efforts to address tributary habitat, hatchery, and predation impacts.

Immediate implementation of certain actions is expected to reduce short-term population risk relatively quickly; examples include site-specific projects to (1) protect and restore habitat complexity and diversity, (2) provide access to side channels and off-channel habitats, and (3) protect or restore floodplain connectivity and function. The benefits of other actions, such as restoring riparian conditions to improve watershed function, will not be felt for years or decades after implementation. For many populations, actions are needed soon to start reducing the impact of hatchery-origin fish so that populations can become self-sustaining as habitat conditions improve. A first step in this process is to develop population-specific transition strategies that specify how and when hatchery strategies described in the management unit plans will be implemented.

Key uncertainties that need to be addressed to support implementation of near-term actions for Lower Columbia River steelhead relate to techniques for reducing pHOS and increasing passage efficiencies past tributary dams, and the pace at which reintroduced populations become functional and self-sustaining (see Section 9.6.7).

[45] Implementation of recovery actions to reduce threats in each category is already under way, although the scale of effort is less than that called for in this recovery plan.

The subsections below describe recovery strategies and near-term and long-term priorities for each threat category. For specific management actions in each threat category, linked to population and location, see the management unit plans (LCFRB 2010a and ODFW 2010).

### 9.6.2 Tributary Habitat Strategy

Lower Columbia River steelhead will benefit from the regional tributary strategy described in Section 4.1.2. The regional strategy is directed toward protecting and restoring high-quality, well-functioning salmon and steelhead habitat through a combination of (1) site-specific management actions that will protect habitat and provide benefits relatively quickly, (2) watershed-based actions designed to protect or restore habitat-forming processes and provide benefits over the long term, and (3) landscape-scale programmatic actions that affect a class of activities (such as stormwater management or forest practices) over multiple watersheds. Actions of particular benefit to steelhead focus on protecting and restoring habitat complexity and diversity, access to side channels and off-channel habitats, and floodplain connectivity and function in high-priority stream reaches. Improving riparian cover and recruitment of large wood to streams also will be a priority. The subsections below summarize additional, stratum-specific tributary habitat strategies for steelhead.

#### *9.6.2.1 Cascade Winter and Summer Steelhead Tributary Habitat Strategies*

In implementing the tributary habitat strategy for the Cascade strata, considerations include the following:

- Generally, habitat conditions are favorable in the upper portions of the Cowlitz, Cispus, and North Fork Lewis subbasins, where winter steelhead populations are targeted for viability but where access has been blocked by dams. In these areas, protecting high-quality habitat and restoring upslope processes that improve and maintain habitat quality will be priorities. Large portions of these areas are in federal forest land; this highlights the importance of implementing the Northwest Forest Plan to protect habitats in those areas.

- Habitat conditions are also generally favorable in the Sandy subbasin (the Sandy winter steelhead population is targeted for very high persistence probability). Again, large portions of this subbasin are in federal forest land. Implementation of the City of Portland's Bull Run water supply habitat conservation plan also will improve habitat quality and increase the amount of habitat available to Sandy winter steelhead.

- Substantial restoration effort will be needed in areas currently accessible to Lower Columbia River steelhead. Because steelhead use mid- to upper-basin habitats for spawning and rearing, restoration efforts will focus on such areas, both in historically highly productive watersheds and in areas where production potential is more limited. Specific actions will include those described above for Lower Columbia River steelhead generally.

- State or private forest land predominates in the upper portions of the Toutle, Kalama, and North Fork Lewis subbasins, and the upper portions of the East Fork Lewis and Washougal subbasins also are forested, with state/federal and private/federal ownership, respectively. These forest lands must be managed to protect and restore watershed processes (such as by implementing the Northwest Forest Plan and Washington's habitat conservation plan for state-owned forest land and Forest Practices Rules for private forest land).

- Managing the impacts of growth and development will be important in all subbasin but particularly in the Washougal, where human population growth is expected to be large.

- In all subbasins, but particularly in the East Fork Lewis, restoring lowland floodplain function, riparian function, and stream habitat diversity will be important. The historically active floodplain and channel migration zone in the lower mainstem East Fork Lewis has been drastically altered by modifications to protect rural residential development, agricultural land, and gravel mining operations.

In addition to the actions described as part of the regional strategy for tributary habitat, addressing passage barriers such as culverts will benefit steelhead by restoring access to habitat in a number of locations; in some cases, additional assessment is needed to inventory passage barriers and prioritize them for removal or improvement. For the North Fork Toutle winter steelhead population, addressing sedimentation and passage issues at the North Fork Toutle sediment retention structure will be key. In the Sandy subbasin, municipal water withdrawals by the City of Portland have adverse effects on instream flows and are being addressed by implementation of the city of Portland's Bull Run Water Supply habitat conservation plan.

Assuming that the impacts of other threats are reduced to the levels shown in Table 9-7, the scale of habitat improvements that will be needed for Cascade winter steelhead populations ranges from minimal in the case of the Salmon Creek and Sandy populations (the Salmon Creek population is targeted to be maintained at its baseline status, and habitat conditions in the Sandy subbasin are generally good) to reductions of 50 percent (Upper Cowlitz, Cispus, Tilton) or more (Clackamas) in baseline habitat impacts to tributary habitat productivity.[46]

The scale of habitat improvements needed for Cascade summer steelhead populations ranges from minimal in the case of the Kalama and North Fork Lewis populations (which are targeted for high and very low persistence probabilities, respectively) to a 20 percent reduction in baseline tributary habitat impacts in the Washougal and a 50 percent reduction in the East Fork Lewis.

[46] The Oregon management unit plan notes that achieving the level of habitat improvement identified to meet the target status of high persistence probability for the Clackamas winter steelhead population is not feasible (ODFW 2010, p. 195). It is possible that the Cascade winter steelhead stratum would meet the WLC TRT's viability criteria for high probability of stratum persistence even if the Clackamas population were maintained at its baseline status, depending on the outcome of recovery efforts for other populations in the stratum.

#### *9.6.2.2 Gorge Winter and Summer Steelhead Tributary Habitat Strategies*

In implementing the tributary habitat strategy for the Gorge strata, considerations include the following:

- Gorge populations occur in watersheds that are largely federal, state, and private forest land. These lands must be managed to protect and restore watershed processes.

- In the lower reaches of most Gorge tributary streams, floodplains have been drastically altered or disconnected as a result of channel modification to facilitate and protect development and agricultural land.

- Water quality and flow in the Hood subbasin are adversely affected by water withdrawals for irrigation, low-head hydropower, and the use of agricultural chemicals.

- For the Lower and Upper Gorge winter steelhead populations, site-specific actions will include addressing or mitigating the impacts of the highway and railroad transportation corridors that run parallel to the Columbia River shoreline, traversing all creek drainages in ways that restrict access and disconnect upland and lowland habitat processes.

In addition to the actions described as part of the regional strategy for tributary habitat, for the Hood summer population, reduced instream flow from irrigation withdrawals is a primary threat, so actions to identify and implement flow improvements will be important.

Assuming that the impacts of other threats are reduced to the levels shown in Table 9-7, reductions in baseline tributary habitat impacts needed to meet target statuses for Gorge winter steelhead populations are on the order of 20 to 40 percent for the Upper and Lower Gorge winter steelhead populations. For the Hood population, although existing habitat appears to be adequate, the Oregon management unit plan expects that habitat actions benefitting other species will also benefit winter steelhead.

Assuming that the impacts of other threats are reduced to the levels shown in Table 9-7, the scale of habitat improvements needed to meet targets for Gorge summer steelhead populations ranges from minimal, for the currently viable Wind summer population,[47] to an 85 percent reduction in baseline tributary habitat impacts for the Hood population. The Oregon management unit plan notes that tributary habitat improvements of this magnitude are not feasible in the Hood subbasin and that the Hood population is unlikely to achieve a high persistence probability (ODFW 2010).

[47] Although the Wind summer steelhead population currently is viable and is not targeted for improvements in abundance and productivity, increases in the diversity of this population are needed for it to achieve recovery goals.

### 9.6.3 Estuary Habitat Strategy

Improving Columbia River estuary habitat as described in the regional estuary habitat strategy will benefit all Columbia Basin ESUs, including Lower Columbia River steelhead. (For a summary of the regional estuarine habitat strategy, see Section 4.2.2.) The regional strategy reflects actions presented in the Oregon and Washington management unit plans to reduce estuarine habitat-related threats and is consistent with actions in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a).

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) assumes that feasible estuarine habitat improvements and predation management measures could result in a maximum increase of 20 percent in the number of outmigrating juveniles leaving the Columbia River estuary. Oregon and Washington recovery planners set targets of reducing anthropogenically enhanced mortality in the estuary for winter steelhead populations based on the estuary module and their own approaches to threat reductions (ODFW 2010 195-199, Tables 6-30 through 6-35; LCFRB 2010a p. 6-66, Table 6-13).

### 9.6.4 Hydropower Strategy

The hydropower recovery strategy for Lower Columbia River steelhead is to address impacts of tributary hydropower dams through implementation of FERC relicensing agreements and thereby reestablish viable winter-run populations in the Upper Cowlitz and Cispus subbasins and achieve survival gains in other populations affected by tributary hydropower facilities.

The strategy also includes measures to improve passage survival at Bonneville Dam for the populations that spawn above Bonneville Dam and implementation of mainstem flow management operations designed to benefit spring migrants from the interior of the Columbia Basin; NMFS expects that these flow management operations will also improve survival in the estuary and, potentially, the plume for all Lower Columbia River salmon and steelhead populations. NMFS estimates that survival of Lower Columbia River steelhead passing Bonneville Dam was 90.6 percent for juveniles from 2002 to 2009 and 98.5 percent for adults from 2002 to 2007 (NMFS 2008a). NMFS expects that implementation of actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will improve juvenile steelhead salmon survival at Bonneville Dam by less than ½ percent, and that adult survival will be maintained at recent high levels (NMFS 2008a). Consequently, Oregon has not incorporated survival benefits from passage improvements at Bonneville into the hydropower threat reduction targets for Oregon populations above Bonneville.[48] The Washington management unit plan assumes that actions identified in the 2008 FCRPS Biological Opinion and its 2010 Supplement will aid adults and juveniles from all steelhead populations originating above Bonneville Dam. For more on actions to improve mainstem dam passage, see the regional hydropower strategy in Section 4.3.2.

[48] Hydropower-related threat reduction targets for Oregon populations above Bonneville Dam are associated with removal of Powerdale Dam on the Hood River.

In its management unit plan, Oregon incorporated several actions addressing impacts of the Columbia River hydropower system that are not included in the FCRPS Biological Opinion and its 2010 Supplement but that Oregon maintains are needed to benefit Lower Columbia River salmon and steelhead populations that spawn above Bonneville Dam. The state of Oregon's position is that the FCRPS action agencies should conduct operations in addition to those incorporated in the FCRPS Biological Opinion to address the needs of ESA-listed salmon and steelhead. Oregon is a plaintiff in litigation against various federal agencies, including NMFS, challenging the adequacy of measures in the FCRPS Biological Opinion and its 2010 Supplement. NMFS does not agree with Oregon regarding the need for or likely efficacy of the additional actions Oregon proposed in that litigation, including the actions in the Oregon management unit plan that are not part of the FCRPS Biological Opinion and its 2010 Supplement. For more detail on these actions and NMFS' view of them, see the regional hydropower strategy in Section 4.3.2.

The subsections below summarize stratum-level hydropower strategies for Lower Columbia River steelhead.

#### *9.6.4.1 Cascade Winter Steelhead Hydropower Strategy*

Passage improvements and hatchery reintroduction programs are the main elements of the hydropower strategy for Cascade winter steelhead. Passage will be created or improved at projects on the Cowlitz (Upper Cowlitz, Cispus, and Tilton populations) and Lewis (North Fork Lewis population) rivers, while hatchery reintroduction programs will be used to reestablish viable winter steelhead populations in the Upper Cowlitz and Cispus subbasins and to improve the persistence probability of the Tilton population (from very low to low) and North Fork Lewis (from very low to medium) population. These changes will be implemented under the terms of FERC relicensing agreements completed with (1) Tacoma Power for the Cowlitz River Project in 2000, and (2) PacifiCorp and the Cowlitz PUD for the Lewis River Hydroelectric Projects in 2004. Habitat above the dams in these systems is relatively intact, with well-functioning watershed processes and a high percentage of federal land ownership.

In the Cowlitz subbasin, Mayfield Dam blocks winter steelhead access to the upper watershed; approximately 40 percent of the spawning and rearing habitat in the Cowlitz subbasin is not accessible. Under a trap and haul program begun in 1994, adult winter steelhead are collected at the Cowlitz hatcheries and released into the Upper Cowlitz, Cispus, and Tilton subbasins. The resulting naturally produced smolts are collected at the Cowlitz Falls Fish Collection Facility, acclimated at the Cowlitz Salmon Hatchery, and released in the mainstem Cowlitz (LCFRB 2010a). Passage at these dams is expected to be improved at some point as part of the 2000 FERC relicensing agreement.[49] Tacoma Power will evaluate fish returns and survival through the reservoirs and assess passage options. Adult passage will be by trap and haul unless certain settlement agreement criteria (fish sorting, productivity, etc.) are met. If they are met, passage at Mayfield Dam is likely to be provided via a new fish ladder, whereas passage at the much larger Mossyrock Dam likely will be provided by either trap and haul or a tramway.

[49] As of fall 2010, Tacoma Power had improved downstream passage survival at Mayfield Dam for juvenile steelhead from the Tilton winter-run population.

In the North Fork Lewis subbasin, three dams (Merwin, Yale, and Swift) block passage to the upper North Fork Lewis, beginning with Merwin Dam at RM 20. As part of the 2004 FERC relicensing agreement for these dams, reintroduction of winter steelhead into habitat upstream of the three dams is being evaluated and is likely to begin in 2012-2013. The keys to successful reintroduction will be adequate passage of juveniles and adults to and from the upper watershed, hatchery supplementation, and habitat improvements. In addition, hydroregulation on the Lewis River has altered the natural flow regime below Merwin Dam, and the flow regime will be need to be adjusted to provide adequate flows for habitat formation, fish migration, water quality, floodplain connectivity, habitat capacity, and sediment transport. However, floodplain and channel alterations in the lower river will limit the ability to restore the natural flow regime, and flow modifications will need to take place in concert with restoration of lower river floodplain function. (LCFRB 2010a)

Maintaining access to headwater spawning areas in the Cowlitz and Lewis systems may become increasingly important because the effects of climate change on stream temperatures may not be as pronounced there (LCFRB 2010a).

In the Clackamas subbasin, PGE's River Mill-Faraday-North Fork Dam complex, which has both upstream and downstream passage facilities, impairs downstream steelhead passage and may also delay adult upstream passage and reduce spawner distribution and success. As part of the 2006 FERC relicensing agreement, PGE agreed to improve downstream juvenile mortality through the dam complex to 3 percent or less and has already rebuilt the ladder and trap at North Fork Dam.

#### *9.6.4.2 Cascade Summer Steelhead Hydropower Strategy*

There are no tributary hydropower dams in the Kalama, East Fork Lewis, or Washougal subbasins. In the North Fork Lewis subbasin, summer steelhead recovery efforts will be focused below Merwin Dam.

#### *9.6.4.3 Gorge Winter and Summer Steelhead Hydropower Strategy*

Tributary hydropower impacts for the Hood winter and summer steelhead populations will be addressed by the removal of Powerdale Dam. The dam, which was operated by PacifiCorp, was removed in 2010 under the terms of a settlement agreement reached in 2003. The dam had passage systems in place; nevertheless, removal is expected to improve upstream and downstream survival, increase access to historical spawning and rearing habitat, and reduce hydropower impacts on Hood winter and summer populations by 55 percent. There are no tributary dams in the Wind subbasin.

Actions in the 2008 FCRPS Biological Opinion and its 2010 Supplement will also provide slight improvements in juvenile survival at Bonneville Dam for the Upper Gorge winter and Hood winter and summer populations (see the regional hydropower strategy in Section 4.3.2).

### 9.6.5 Harvest Strategy

Before the mid-1970s, steelhead harvest impacts were on the order of 70 percent or more. Harvest impacts were reduced in 1975 when the commercial harvest of steelhead in non-treaty fisheries was prohibited, and reduced further in the late 1980s and early 1990s through the implementation of mass marking and hatchery-fish-only retention requirements. For most populations harvest impacts are now 10 percent or less. Harvest impacts to populations above Bonneville Dam are somewhat higher, on the order of 15 percent or less, as a result of the additional impacts that occur in tribal fisheries.

As discussed in Section 9.4.4, although harvest-related mortality is identified as a secondary limiting factor for all populations within the DPS, substantial actions already have been implemented to reduce harvest impacts on natural-origin steelhead. Analysis in the Oregon and Washington management unit plans determined that maintaining steelhead harvest at current levels is consistent with achieving recovery objectives (ODFW 2010, LCFRB 2010a). The harvest strategy is to ensure continued regulation of fisheries to limit impacts to current levels, using ancillary and precautionary actions as described in Section 4.5.2 (the regional harvest strategy).

The Washington plan recommends maintaining harvest impacts on Cascade winter and summer steelhead of between 5 and 10 percent for the 50-year implementation period; this will be accomplished through improved monitoring and application of regulations in mainstem and tributary fisheries. Oregon did not incorporate any reduction to the 10 percent baseline harvest impact rate into its threat reductions for winter steelhead populations. In addition to maintaining current harvest regulations and impacts, the Washington management unit plan recommends (1) continuing to improve gear and regulations to minimize incidental impacts to naturally spawning steelhead, (2) establishing specific triggers for in-season Columbia River fishery adjustments as needed to support lower Columbia River winter steelhead recovery goals and strategies, (3) managing Columbia River commercial fisheries by time, area, and gear to target hatchery fish and minimize impacts to naturally spawning steelhead, and (4) monitoring naturally spawning steelhead encounter rates in tributary recreational fisheries, particularly in populations targeted for viability or high persistence probability.

#### *9.6.5.1 Cascade Winter and Summer Steelhead Harvest Strategy*

The DPS-level harvest strategies will benefit populations in the Cascade winter and summer strata.

#### *9.6.5.2 Gorge Winter and Summer Steelhead Harvest Strategy*

The DPS-level harvest strategies will benefit populations in this stratum. In addition, for the Upper Gorge, Wind, and Hood populations, Oregon proposes discussing Zone 6 fishery impacts with tribes to reduce potential additional impacts. Potential actions include extending harvest sanctuaries from tributary mouths and modifying season length or timing (ODFW 2010).

### 9.6.6 Hatchery Strategy

The regional hatchery strategy described in Section 4.4.2 summarizes goals and approaches relevant to Lower Columbia River steelhead. Details of how the hatchery strategy will be implemented in each steelhead stratum will be developed as part of the transition schedules, but the subsections below provide some information.

#### *9.6.6.1 Cascade Winter Steelhead Hatchery Strategy*

Hatcheries will be used in reintroducing winter steelhead in the Upper Cowlitz (Upper Cowlitz, Cispus, and Tilton populations) and North Fork Lewis subbasins. Hatchery-origin adult winter steelhead already are being released upstream of dams to spawn naturally in the Upper Cowlitz, Cispus, and Tilton rivers; these fish come from hatchery programs that were founded with local stock and have not been augmented with non-local stocks. Local stocks will also be used to develop hatchery programs that will be used to reintroduce winter steelhead to the upper Lewis subbasin. WDFW may also consider supplementation programs in some other Cascade populations to bolster natural fish numbers above critical levels in selected areas until habitat is restored to levels where a population can be self-sustaining.

The hatchery strategy involves continued hatchery production as mitigation and for fishery enhancement of winter steelhead in the Lower Cowlitz, Kalama, East Fork Lewis, Salmon Creek, Washougal, Clackamas, and Sandy[50] subbasins. Effective control of reproductive and competitive interactions between hatchery-origin fish and natural populations will be particularly important in these cases, with details varying depending on the population's target status. In addition, although there are no hatchery programs located in the Coweeman, hatchery-produced winter steelhead are released there for fishery enhancement.

For the Clackamas population, a pHOS target of 10 percent will be met by reducing Eagle Creek winter steelhead hatchery releases (from 150,000 to 100,000 beginning in 2009). The Clackamas will be managed initially as an integrated program, with a sliding scale developed for take of wild winter steelhead broodstock.[51] The Sandy subbasin winter steelhead program will also be managed as an integrated program, with a sliding scale developed for take of wild winter steelhead broodstock.

The Clackamas subbasin above North Fork Dam will be maintained as a wild fish sanctuary. No hatchery winter steelhead are currently released, nor are the expected to be released, into the North and South Fork Toutle subbasins.

[50] The Sandy winter steelhead population was targeted for an 80 percent reduction in hatchery impacts. The Oregon management unit plan states that, because of fairly recent changes in the management of the hatchery steelhead program, that target has been met, and current stray rates are lower than the 10 percent objective for this population (ODFW 2010).

[51] ODFW will also explore the feasibility of shifting the Clackamas hatchery winter steelhead program to one that holds and rears fish for an extra year to better mimic their natural life cycle (ODFW 2010).

#### *9.6.6.2 Gorge Winter Steelhead Hatchery Strategy*

In the Hood subbasin, Oregon proposes to install a floating weir to remove stray hatchery winter steelhead and to implement a sliding scale for take of wild winter steelhead broodstock for an integrated hatchery program. There are no hatcheries and no releases of hatchery-origin steelhead at present in the Upper Gorge tributaries, and the Washington plan proposes that this area be maintained as a refuge area for winter steelhead (LCFRB Vol. II). In the Lower Gorge, Oregon proposes to investigate placing a new weir and trap to sort hatchery-origin winter steelhead from natural-origin winter steelhead migrating upstream on Eagle Creek, Tanner Creek, or both. There are no hatcheries or winter steelhead releases in the Washington lower Gorge tributaries currently, and no future releases of hatchery-origin winter steelhead are planned for these tributaries.

#### *9.6.6.3 Cascade Summer Hatchery Strategy*

Fishery enhancement programs are expected to continue in the North Fork Lewis, Kalama, East Fork Lewis, and Washougal subbasins. Washington will develop either integrated or segregated programs in each of these subbasins to meet criteria appropriate to the target status of these populations.

#### *9.6.6.4 Gorge Summer Hatchery Strategy*

The Wind subbasin is expected to be maintained as a refuge area for natural-origin fish. The summer steelhead hatchery program in the Hood subbasin was discontinued in 2009. No future releases of hatchery-origin summer steelhead are planned for the lower Gorge tributaries in Washington.

### 9.6.7 Predation Strategy

The regional predation strategy (see Section 4.6.2) involves reducing predation by birds, fish, and marine mammals and will benefit all Lower Columbia River ESUs, including summer and winter steelhead.

### 9.6.8 Critical Uncertainties

Each aspect of the steelhead recovery strategy has a number of critical uncertainties. For all ESUs, there are uncertainties regarding how habitat actions will translate into changes in productivity and capacity (Roni et al. 2011). Prioritizing and identifying next steps in resolving uncertainties is a near-term priority. Critical uncertainties specific to the Lower Columbia River steelhead recovery strategy include the following:

- Effectiveness of weirs, shifts in production, and other techniques in achieving pHOS targets
- Effectiveness of various approaches to developing integrated hatchery/natural populations, especially for populations with very low natural-origin abundance
- Effective methods of providing adequate downstream passage efficiency for juveniles migrating past tributary dams

- Effectiveness of hatchery reintroduction programs and the pace of local adaptation of reintroduced stocks above tributary dams

- Most appropriate boundary between Mid-Columbia and Lower Columbia River steelhead DPSs[52]

These critical uncertainties represent preliminary priorities identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); as described in Chapter 10, additional discussion among local recovery planners and NMFS staff will be needed to finalize future research priorities for Lower Columbia River steelhead.

The management unit plans identify more comprehensive critical uncertainties and research, monitoring, and evaluation needs that, along with the list above, will provide the basis for these future discussions. The Washington management unit plan has a discrete section on critical uncertainties for all of the ESUs in general (see Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the *Lower Columbia Fish Recovery Board completed the Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties. The list above does not include critical uncertainties that apply to multiple ESUs; these will be discussed and considered as decisions are made in implementation. In addition, the critical uncertainties above are of a technical nature; there are also many critical uncertainties related to social, political, and economic issues.

Critical uncertainties are one element of research, monitoring, and evaluation (RME) and adaptive management, which will be key components of the steelhead recovery strategy (see Chapter 10 for more discussion of RME and adaptive management for this recovery plan).

## 9.7 Delisting Criteria Conclusion for LCR Steelhead

The requirement for determining that a species no longer requires the protection of the ESA is that the species is no longer in danger of extinction or likely to become endangered within the foreseeable future, based on evaluation of the listing factors specified in ESA section 4(a)(1). To remove the Lower Columbia River steelhead DPS from the Federal List of Endangered and Threatened Wildlife and Plants (that is, to

[52] In its 2011 5-year review (76 *Federal Register* 50448), NMFS discussed uncertainties regarding the most appropriate boundary between the Mid-Columbia and Lower Columbia River steelhead DPSs. New information, primarily DNA microsatellite variation, underscores the transitional nature of populations in this area and the uncertainty associated with the ESU and DPS boundaries there. Given all this information, it might be reasonable either to reassign the White Salmon and Klickitat River steelhead from the Middle Columbia River DPS to the Lower Columbia River DPS or to maintain the existing DPS boundary. NMFS recommended maintaining the existing boundary but will reexamine the issue in future 5-year reviews as new information becomes available.

delist the DPS), NMFS must determine that the DPS, as evaluated under the ESA listing factors, is no longer likely to become endangered.

The ESA requires that recovery plans, to the maximum extent practicable, incorporate objective, measurable criteria that, when met, would result in a determination in accordance with the provisions of the ESA that the species be removed from the Federal List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12). The recovery criteria in this plan (both biological and threats criteria) meet this statutory requirement.

As described in Section 9.3, if the scenario in Table 9-4 were achieved, it would meet or exceed the WLC TRT's viability criteria, particularly in the Cascade winter stratum but also in the Cascade summer stratum (see Table 9-8).[53] Exceeding the criteria in the Cascade stratum was intentional on the part of local recovery planners to compensate for uncertainties about the feasibility of meeting the WLC TRT's criteria in the Gorge stratum, in particular the questions raised by Oregon about the feasibility of meeting the target status for the Hood summer population.

**Table 9-8**
*Steelhead Recovery Scenario Scores Relative to WLC TRT Viability Criteria*

| Species | Number of Primary Populations | | | | Stratum Average Criteria | | |
|---|---|---|---|---|---|---|---|
| | | Cascade | Gorge | Total | | Cascade | Gorge |
| Winter Steelhead | n ≥ high | 9 | 2 | 11 | Avg. score | 2.61 | 2.33 |
| | TRT criterion (n ≥ 2) met? | Yes | Yes | | TRT criterion (avg. ≥ 2.25) met? | Yes | Yes |
| Summer Steelhead | n ≥ high | 3 | 2 | 5 | Avg. score | 2.38 | 3.50 |
| | TRT criterion (n ≥ 2) met? | Yes | Yes | | TRT criterion (avg. ≥ 2.25) met? | Yes | Yes |

Source: Based on LCFRB (2010a), Table 4-7.

Oregon recovery planners raised questions about the feasibility of meeting the recovery target of high persistence probability for both the Clackamas winter and Hood summer steelhead populations (ODFW 2010, Table 6-36). The Oregon management unit plan states that achieving a high probability of persistence for the Clackamas population would require more tributary habitat improvements than are believe feasible (ODFW 2010, Table 3-30). Because the recovery scenario targets nine steelhead populations for high persistence probability in the Cascade stratum, the WLC TRT criteria would likely

[53] As discussed in Section 2.5.4, the TRT's criteria for high probability of stratum persistence require that two or more populations be viable and that the average score for all populations in the stratum be 2.25 or higher. In the Cascade winter stratum, nine populations are targeted for high or very high persistence probability, and, using the WLC TRT's scoring system, the average viability score for all populations in the stratum would be 2.61.

be met even without achieving high persistence probability for the Cascade winter population.

Oregon recovery planners' uncertainty regarding the Hood summer steelhead population is based in part on questions about the feasibility of meeting the habitat and hatchery threat reduction targets for this population (ODFW 2010) and in part on questions raised by both Oregon and Washington management unit planners regarding Gorge stratum and population delineations and the historical role of the Gorge populations (LCFRB 2010a, ODFW 2010). These questions include whether the Gorge populations were highly persistent historically, whether they functioned as independent populations within their stratum in the same way that the Coast and Cascade populations did, and whether the Gorge stratum itself should be considered a separate stratum from the Cascade stratum.

As discussed in Section 3.2, NMFS has considered the WLC TRT's viability criteria (from McElhany et al. 2003 and 2006 and summarized in Table 2-3), the additional recommendations in McElhany et al. (2007), the recovery scenarios and population-level goals in the management unit plans, and the questions raised regarding the historical role of the Gorge strata.

NMFS has concluded that the WLC TRT's criteria adequately describe the characteristics of a DPS that meet or exceed the requirement for determining that a species no longer needs the protection of the ESA. These criteria provide a framework within which to evaluate specific recovery scenarios. NMFS has evaluated the recovery scenario presented in the management unit plans for Lower Columbia River steelhead (summarized in Table 3-1 of this recovery plan ) and the associated population-level abundance and productivity goals (see Section 9.3) and has concluded that they also adequately describe the characteristics of a DPS that no longer needs the protections of the ESA. NMFS endorses the Lower Columbia River steelhead recovery scenario and the associated population-level goals in the management unit plans (summarized in Table 3-1 and Section 9.3) as one of multiple possible scenarios consistent with delisting.

NMFS also agrees with the management unit planners that the historical role of the Gorge populations and strata merits further examination. The extent to which compensation in the Cascade stratum is ultimately considered necessary to achieve an acceptably low risk at the DPS level will depend on how questions regarding the historical role of the Gorge populations are resolved.

NMFS therefore has developed the following delisting criteria for the Lower Columbia River steelhead DPS. (NMFS has amended the WLC TRT's criteria to incorporate the concept that each stratum should have a probability of persistence consistent with its historical condition, thus allowing for resolution of questions regarding the Gorge strata):

1. All strata that historically existed have a high probability of persistence or have a probability of persistence consistent with their historical condition. High probability of stratum persistence is defined as:

a. At least two populations in the stratum have at least a 95 percent probability of persistence over a 100-year time frame (i.e., two populations with a score of 3.0 or higher based on the TRT's scoring system).

b. Other populations in the stratum have persistence probabilities consistent with a high probability of stratum persistence (i.e., the average of all stratum population scores is 2.25 or higher, based on the TRT's scoring system). (See Section 2.6 for a brief discussion of the TRT's scoring system.)

c. Populations targeted for a high probability of persistence are distributed in a way that minimizes risk from catastrophic events, maintains migratory connections among populations, and protects within-stratum diversity.

A probability of persistence consistent with historical condition refers to the concept that strata that historically were small or had complex population structures may not have met Criteria A through C, above, but could still be considered sufficiently viable if they provide a contribution to overall ESU viability similar to their historical contribution.

2. The threats criteria described in Section 3.2.2 have been met.

# 10. Adaptive Management and Research, Monitoring, and Evaluation

The long-term success of recovery efforts for Lower Columbia River salmon and steelhead will depend on the strategic use of research, monitoring, and evaluation (RME) to provide useful information to decision makers within an adaptive management framework. Research, monitoring, and evaluation programs associated with recovery plans need to gather the information that will be most useful in tracking and evaluating implementation and action effectiveness and assessing the status of listed species. Planners and managers then need to use the information collected to guide and refine recovery strategies and actions. These elements of recovery plans are crucial for salmon and steelhead because of the complexity of the species' life cycles, the range of factors affecting survival, and the limits on our understanding of how specific actions affect species' characteristics and survival.

Research, monitoring, and evaluation for salmon and steelhead are complicated by the existence of multiple entities in the region conducting relevant monitoring. Within the Columbia Basin and the Lower Columbia recovery subdomain, many organizations, including federal, state, tribal, local, and private entities, conduct various kinds of monitoring. Developing regional coordination for these efforts is essential if we are to design and implement sound monitoring programs that provide relevant, valid, and accessible data and use limited resources most effectively.

The management unit recovery plans contain or will contain specific RME plans for their areas. These RME plans are based on regional guidance for adaptive management and RME and will guide recovery planning RME efforts and funding in their respective areas, within a context of ongoing regional guidance and coordination.

This chapter provides the following information:

- A brief description of the concept of adaptive management and a brief overview of salmon and steelhead recovery plan RME needs
- A summary of regional guidance for adaptive management and RME
- An overview of the RME components of each management unit plan and the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a)
- An overview of RME regional coordination efforts and needs[1]

## 10.1 Overview of Adaptive Management and RME Needs

Adaptive management is the process of adjusting management actions and/or overall approach based on new information. Adaptive management works by coupling decision

[1] For a list of preliminary critical uncertainties for each ESU, see Sections 6.6.8, 7.4.3.8, 7.5.3.8, 7.6.3.6, 8.6.8, and 9.6.7.

making with data collection and evaluation. Most importantly, it works by offering an explicit process through which alternative approaches and actions can be proposed, prioritized, implemented, and evaluated (NMFS 2007). Successful adaptive management requires that monitoring and evaluation plans be incorporated into overall implementation plans for recovery actions. These plans should link monitoring and evaluation results explicitly to feedback on the design and implementation of actions. In adaptive management, recovery strategies are treated like working hypotheses that can be acted upon, tested, and revised (Lee 1999). Figure 10-1 illustrates the adaptive management process.

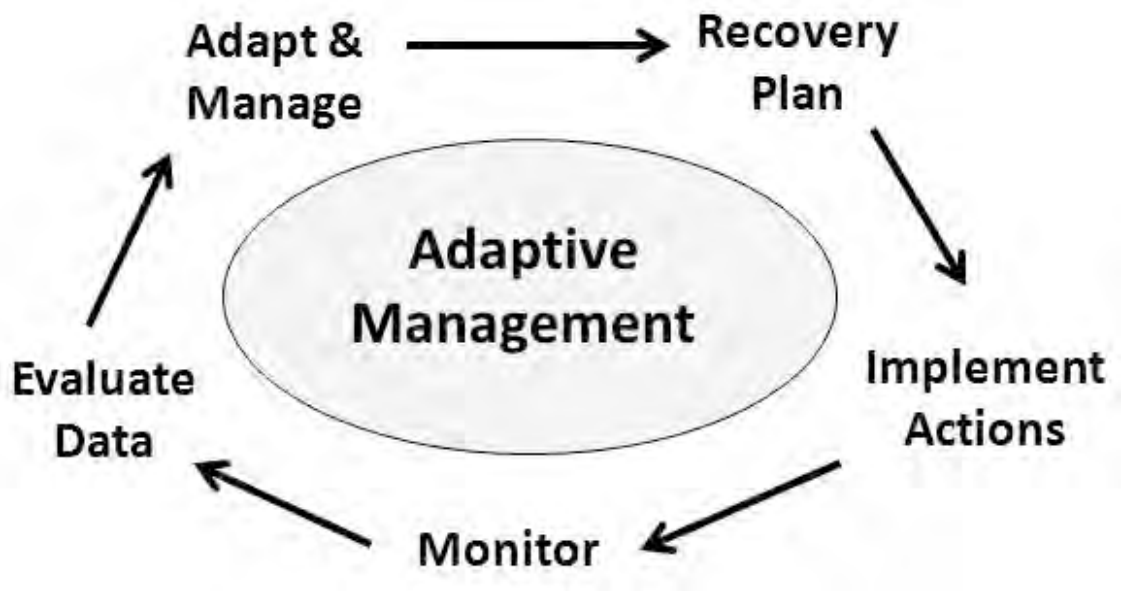


**Figure 10-1.** *The Adaptive Management Cycle*

Several types of monitoring are needed to support adaptive management (NMFS 2007):

- Implementation monitoring and compliance monitoring, which are used to evaluate whether recovery plan actions are being implemented as directed.
- Status and trend monitoring, which assesses changes in the status of an ESU and its component populations, and changes in the status or significance of the threats to an ESU.
- Effectiveness monitoring, which tests hypotheses about cause-and-effect relationships and determines via research whether an action is effective and should be continued.

It is also important to explicitly address the many unknowns in salmon recovery—the "critical uncertainties" that make management decisions much harder. Doing so will involve prioritizing critical uncertainties and ensuring that appropriate research is conducted that can inform managers on the questions (NMFS 2007).

Finally, given the wide array of organizations involved in salmon recovery in the Columbia Basin, including groups from federal agencies, states, and tribes, the task of coordinating all the information being gathered and making it available to decision makers throughout the region is daunting. During the last decade, substantial progress has been made in standardizing fisheries data collection and storage methods.

## 10.2 Guidance for Adaptive Management and RME

NMFS and other entities have developed documents to guide and coordinate salmon and steelhead RME efforts throughout the Columbia Basin and the Pacific Northwest. Overall, the goal of these guidance documents is to ensure that monitoring programs are designed to provide the information NMFS and others need to understand the effects of recovery actions and evaluate the status of salmon and steelhead populations and the threats they face. Another objective of the guidance documents has been to ensure that data is managed, shared, and integrated in a cost-effective manner. The primary guidance documents are described briefly below.

### 10.2.1 Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance

In 2007, the NMFS Northwest Region released *Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance* (NMFS 2007). This document describes the questions NMFS asks in evaluating species status and making listing and delisting decisions. It offers conceptual-level guidance, not specific instructions, on gathering the information that will be most useful in tracking progress and assessing the status of listed species.

As outlined in the document, a delisting decision is based on evaluation of both the ESU's biological status and the extent to which the threats facing the ESU have been addressed. The document spells out the questions that need to be answered through RME to satisfy the requirements for each component of such a decision. These components are displayed graphically in the form of a "listing status decision framework" (Figure 10-2).

The document emphasizes that adaptive management is an experimental approach in which the assumptions underlying recovery strategies and actions are clearly stated and subject to evaluation (NMFS 2007). It further states that a monitoring and evaluation plan to support adaptive management should provide (1) a clear statement of the metrics and indicators by which progress toward achieving goals can be tracked, (2) a plan for tracking such metrics and indicators, and (3) a decision framework through which new information from monitoring and evaluation can be used to adjust strategies or actions aimed at achieving the plan's goals.

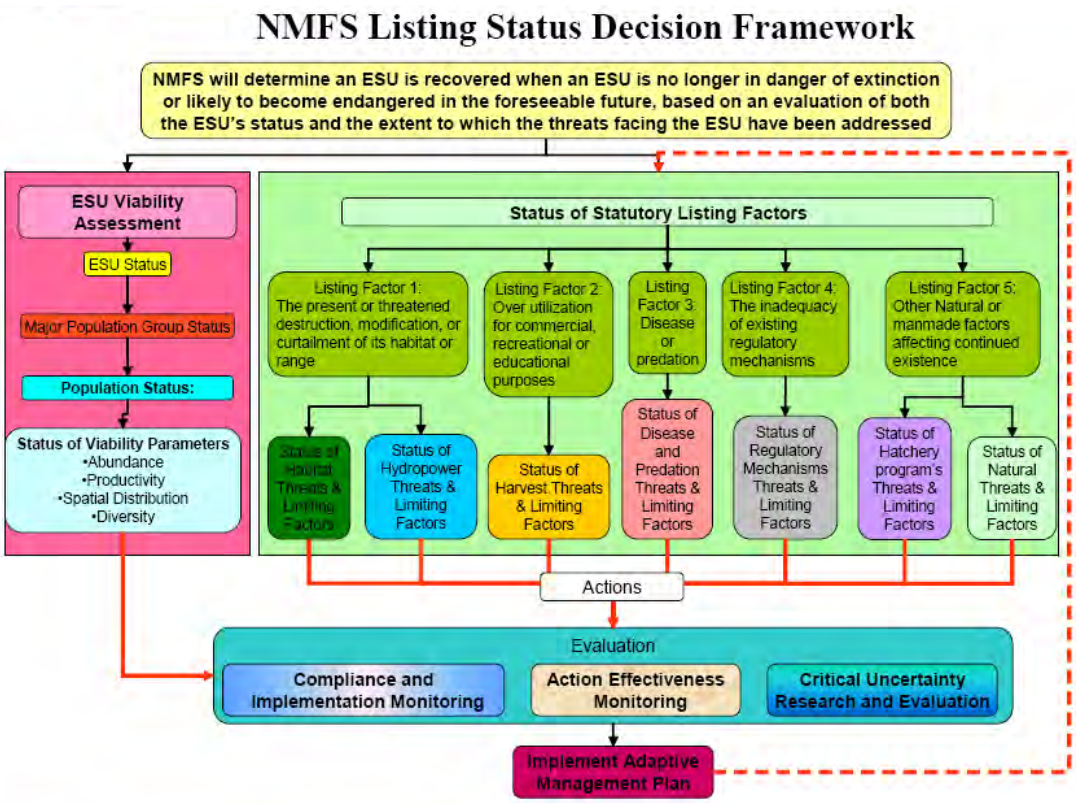


**Figure 10-2.** *NMFS Listing Status Decision Framework*

The document also discusses the various types of monitoring needed for salmon recovery, categorized as status and trend monitoring, effectiveness monitoring, validation monitoring, implementation monitoring, and research on critical uncertainties.

- **Status and trend monitoring**. Status monitoring is used to characterize existing conditions and establish a baseline for future comparisons. For monitoring of salmon and steelhead population status, the parameters of interest are abundance, productivity, diversity, and spatial structure. Parameters also need to be established to monitor the status of threats to salmon and steelhead (e.g., habitat, hydropower, hatcheries, and harvest). Trend monitoring involves measurements taken at regular time or space intervals to assess the long-term or large-scale trend in a particular parameter (NMFS 2007).

- **Effectiveness monitoring.** Effectiveness monitoring evaluates the direct effect of management actions. Success can be measured against reference areas, baseline conditions, or desired future conditions. Effectiveness monitoring can be implemented at the scale of individual actions, suites of actions across space, or for an entire strategy consisting of multiple actions at a single location.

- **Validation monitoring.** Validation monitoring answers the question: Did the management actions create the intended outcome? This question often involves evaluating the effects of numerous projects on a watershed or species. An example

would be evaluating whether the cumulative effects of habitat restoration actions in a specific river basin resulted in increased production of juvenile salmon.

- **Implementation monitoring.** Implementation monitoring determines whether activities were carried out as planned and is generally conducted as an administrative review or site visit. This type of monitoring cannot directly link restoration actions to physical, chemical, or biological responses because none of these parameters are measured (NMFS 2007).

- **Research on critical uncertainties.** The adaptive management guidance notes that research on critical uncertainties may seem expensive or unnecessary but in the long run will reduce monitoring and implementation costs (NMFS 2007).

Finally, the adaptive management guidance (NMFS 2007) discusses considerations for prioritizing monitoring and examines the consequences of different sorts of incomplete data. Management and delisting decisions often must be made with incomplete information. Different types of incomplete information pose correspondingly different types of risks for delisting decisions. This discussion is intended to help planners consider how their own implementation and monitoring decisions may affect NMFS' assessment of ESU status.

### 10.2.2 Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead

Another document from the NMFS Northwest Region, *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead* (Crawford and Rumsey 2011), builds on the 2007 adaptive management guidance document with specific recommendations for monitoring, data collection, and reporting ESA information (Crawford and Rumsey 2011). NMFS intends this document to assist those involved with salmon recovery in understanding the desired level of monitoring and the associated level of certainty needed at the regional, local, and project levels to support ESA status evaluations and listing and delisting decisions. NMFS also intends the guidance to assist in the development and implementation of a regional monitoring strategy that will provide the necessary monitoring information in the most cost-effective way for the region. The document does not establish new requirements or modify any existing requirements.

The recommendations included are for federal and state agencies, tribes, local governments, and watershed organizations. Recommendations include monitoring that addresses all of the viable salmonid population (VSP) criteria and the threats to salmon and steelhead (organized under the five ESA listing factors). The guidance also makes recommendations for setting up regional databases and coordinating regional data collection so that the various agencies and tribes involved in salmon recovery can share data as well as report it efficiently to NMFS.

Recommendations for VSP monitoring address adult spawner abundance, productivity, spatial distribution, and diversity. Abundance considerations include use of a sampling design that has known precision and accuracy, monitoring of hatchery contributions, and a goal of a coefficient of variation of 15 percent or less for all populations. Productivity considerations include (1) developing at least 12 brood years of spawner

information to allow use of the geometric mean of recruits per spawner to develop productivity estimates, and (2) obtaining estimates of juvenile migrants for at least one significant population within each stratum. The guidance recommends certainty levels for detecting changes in spatial distribution and, for diversity, suggests short-term strategies (use of spawn timing, age distribution, and other observations) and long-term strategies (genetic baseline information for each population).

Habitat-related recommendations include use of a generalized random tessellation stratified (GRTS) sampling program coupled with remote sensing of land use and land cover and coordinated with fish-in/fish-out monitoring where possible. Implementation of habitat restoration efforts should be capable of being reported (e.g., using the data fields in the Pacific Coastal Salmon Recovery Fund [PCSRF] project tracking database) and correlated with limiting factors as defined in the NMFS data dictionary (Hamm 2012). Reach-scale effectiveness monitoring should be conducted for various habitat improvement categories using a Before and After Control Impact (BACI) design wherever possible. There should also be at least one intensively monitored watershed (IMW) in each recovery subdomain. The U.S. Environmental Protection Agency, state agencies, and local governments should monitor stormwater and cropland runoff for concentrations of toxic contaminants and to identify their sources. For monitoring of hydropower-related threats, the guidance largely refers to specific requirements that have been written into FERC licenses.

For monitoring of harvest status and trends, the NMFS monitoring guidance notes the need for improved estimates of population-level harvest impacts, improved models for predicting harvest impacts to populations, and improved monitoring of incidental take and exploitation rate management.

For disease and predation, the guidance suggests that the status of existing invasive species should be compiled for each ESU/DPS and that watershed-level assessments should be conducted for species known to affect salmon and steelhead.

For threats related to hatchery production, the guidance recommends that states and tribes be able to determine annually and with known precision the proportion of hatchery origin spawners (pHOS) for each population. The proportion of natural influence (PNI) for primary populations with supplementation programs should be calculated periodically. Hatchery operators should complete Hatchery and Genetics Management Plans (HGMPs), submit them to NMFS for approval, and track and report on their implementation. Hatchery action effectiveness monitoring should include development of large-scale treatment/reference design to evaluate long-term trends in abundance and productivity of supplemented populations.

To evaluate the adequacy of regulatory actions, the guidance notes the need for a recovery action tracking system capable of recording whether entities have implemented regulatory actions in the recovery plans. It also suggests development of a randomized sampling program to test whether permits issued under regulatory programs designed to protect riparian and instream habitat are in compliance and adequately enforced.

Noting the regional needs to coordinate data collection, evaluation, and reporting, the guidance also makes the following recommendations: (1) regional environmental

databases should be coordinated such that information can be readily reported to NMFS and shared among participants, (2) methods and calculations used to assess and evaluate data should be transparent and repeatable, (3) all project tracking should be consistent with the PCSRF project tracking database and the NMFS data dictionary, (4) regional salmon recovery partners should build a distributed data system that can communicate among agencies and report to the public, (5) sampling programs for habitat, water quality, and fish VSP criteria should be coordinated to fit within an integrated master sample program.

### 10.2.3 Other RME Guidance

A number of other regional efforts provide guidance relevant to developing RME and adaptive management programs for Lower Columbia River salmon and steelhead. These include Columbia River Basin Fish and Wildlife Program 2009 amendments and recommendations for implementing RME for the 2008 NOAA Fisheries FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a).

#### *10.2.3.1 Columbia River Basin Fish and Wildlife Program 2009 Amendments*

The Northwest Power and Conservation Council's Fish and Wildlife Program emphasizes implementation of fish and wildlife projects based on needs identified in subbasin plans, federal biological opinions, ESA recovery plans, and the 2008 Fish Accords signed by federal agencies, Indian tribes, and the states of Idaho and Montana. The program amendments also establish reporting guidelines and the use of adaptive management to guide decision making and emphasize a more focused monitoring and evaluation framework coupled with a commitment to use the information obtained to make better decisions. The program includes general guidelines for monitoring and adaptive management in the Columbia Basin as well as a discussion of the need to develop a monitoring, evaluation, research, and reporting plan. A description of the program is available at http://www.nwCouncil.org/library/2009/2009-09/Default.asp.

#### *10.2.3.2 Recommendations for Implementing Research, Monitoring and Evaluation for the 2008 NOAA Fisheries FCRPS Biological Opinion (AA/NOAA/NPCC RM&E Workgroups, June 2009 and May 2010)*

Completion of the 2008 Biological Opinion on the operation of the Federal Columbia River Power System (FCRPS) stimulated collaboration related to RME in the mainstem lower Columbia River and estuary. The 2008 FCRPS Biological Opinion and its 2010 Supplement recommended a complex suite of actions to improve survival of salmonids through the migratory corridor of the Columbia River and to improve habitat below Bonneville Dam used for resting, feeding, the physiological transition for fresh to salt water, and migration. Subsequently, federal, state, and tribal entities organized technical work groups to determine how best to implement the recommendations in the Biological Opinion and its Supplement and how to conduct RME to support them. Various guidance documents have been produced through this process and are available at http://www.salmonrecovery.gov/ResearchReportsPublications.aspx.

#### *10.2.3.3 Salmon Monitoring Advisor*

The Salmon Monitoring Advisor is a website developed by the Pacific Northwest monitoring community to provide a comprehensive, technically rigorous framework to help practitioners, decision makers, and funders design monitoring programs. The monitoring advisor is a web-based system that synthesizes a wide array of information into a systematic framework that offers an organized, structured procedure to help users efficiently design and implement reliable, informative, and cost-effective salmon monitoring programs. It provides advice and guidelines to help users systematically work through the numerous steps involved in designing, implementing, and analyzing results from monitoring programs to meet particular monitoring objectives. The address for this site is https://salmonmonitoringadvisor.org/.

## 10.3 RME Plans for the Washington, Oregon, and White Salmon Management Unit Plans

Within the framework of the guidance described above, local recovery planners have or will develop RME programs for their management unit recovery plans. These plans will provide conceptual-level guidance to RME implementation efforts at the local and regional scale. Implementation of these RME plans will also be influenced by the regional coordination efforts described below. Management unit RME plans are briefly summarized below; readers should consult the management unit plans themselves for detail.

### 10.3.1 Washington Management Unit

The Washington management unit plan (LCFRB 2010a) contains a monitoring and research chapter (see LCFRB 2010a, Chapter 9), which is supplemented by the *Research, Monitoring, & Evaluation Program for Lower Columbia Salmon & Steelhead* (LCFRB 2010b). Together these documents provide the framework for a systematic approach to RME in the LCFRB planning area.

Both documents describe general RME strategies for (1) biological status and trend monitoring, (2) habitat status and trend monitoring, (3) implementation/compliance monitoring, (4) action effectiveness monitoring, and (5) uncertainty and validation research. For each of these monitoring elements, the documents identify objectives, strategies, indicators, sampling and analytical design, and implementation actions needed for the RME program. In addition, the RME program document (LCFRB 2010b) contains inventories of available information and data and identifies critical information needs and priorities.[2] Both documents also address information reporting strategies. Because there is significant overlap between the two documents, they are referred to collectively here as the LCFRB RME program. In general, the LCFRB RME program identifies what needs to be done and how to do it but does not address specific implementation details such as desired confidence levels, statistical power, data collection protocols, and sample sizes. (For biological status and trends and habitat status and trends, such implementation details are being developed through the Pacific

[2] In particular, see Appendix B, "Detailed Inventory of Ongoing Monitoring Activities," and Appendix D, "Gap Analysis of Biological Monitoring Programs."

Northwest Aquatic Monitoring Partnership's Integrated Status and Trend Monitoring process, described below in Section 10.6.2).

The LCFRB RME program is intended to integrate with and complement other state and regional RME efforts for salmon and steelhead. Its goal is to provide a template for action and overall guidance to the extensive group of participants involved in implementation of the LCFRB plan. Specific elements are described briefly below.

#### *10.3.1.1 Biological Status Monitoring*

The LCFRB RME program's strategic approach for biological status monitoring is that while the status of every population needs to be assessed, all populations do not need to be monitored. The program advocates assigning the highest priorities for monitoring to populations targeted for high persistence probability and large improvements, and ensuring that populations selected for intensive monitoring represent all strata. For sampling and analytical design, the program recommends a stratified, representative, multi-level sampling framework. Such a sampling design would provide information on every population but sample different populations at different intensities and be designed to ensure representative coverage of all ESUs.

The program also identifies specific needs for a comprehensive natural coho sampling program, expanded adult and juvenile chum sampling efforts, and augmented sampling for adult and juvenile fall Chinook and winter steelhead.

#### *10.3.1.2 Habitat Status Monitoring*

The LCFRB RME program recommends monitoring stream corridor and landscape-scale habitat status as well as water quantity and quality. For stream habitat the strategic approach is to use a rotating panel of habitat samples to produce evaluations relative to baseline conditions every 12 years. The program also calls for assessing landscape condition at 12-year intervals, with landscape-scale information to be compiled uniformly across the entire study area. The primary focus of the LCFRB water quantity and water quality RME program is to characterize conditions for salmon and watershed health relative to a baseline at listing. The plan calls for comprehensive assessments of water quality and quantity status and trends at 12-year intervals.

#### *10.3.1.3 Implementation and Compliance Monitoring*

The LCFRB RME program identifies the need for implementation and compliance monitoring to determine whether recovery actions have been implemented as planned. The program proposes that this be accomplished by having implementing partners evaluate and report on progress in implementation through a centralized database system, called SalmonPORT, to be developed and maintained by LCFRB.

#### *10.3.1.4 Action Effectiveness Monitoring*

The LCFRB RME program addresses action effectiveness monitoring for actions in the categories of stream habitat, hydropower, fisheries, hatcheries, ecological interactions, and mainstem/estuary habitat.

- **Stream Habitat.** For stream habitat, the overall approach is to complete comprehensive assessments of habitat action effectiveness every 6 years. The strategy includes monitoring the effectiveness of specific types of habitat actions, developing and maintaining an inventory of habitat-related actions, and intensively monitoring a subset of habitat actions using formal statistical research design methods. For sampling and analytical design, the plan generally adopts monitoring designs and protocols developed by the Washington Salmon Recovery Funding Board.

- **Hydropower.** For hydropower actions, effectiveness monitoring is intended to determine whether hydropower actions for fish protection, restoration, and mitigation reduce or limit effects on natural-origin fish to levels consistent with conservation and recovery. The strategy calls for evaluating action effectiveness for passage, habitat protection and restoration, reintroduction, and other mitigation actions at all significant tributary and mainstem facilities every 6 years, using criteria as established in FERC licenses, biological opinions, and settlement agreements.

- **Harvest.** The overall objectives for fisheries action effectiveness monitoring include determining whether impacts are limited to prescribed levels and consistent with long-term recovery goals. The strategic approach is to monitor annual impacts and complete comprehensive assessments at 6-year intervals.

- **Hatcheries.** Overall objectives for hatchery action effectiveness monitoring include monitoring to determine whether hatchery impacts on each population are limited to prescribed levels and whether hatchery performance is consistent with goals for each hatchery program. The overall strategy is to monitor each hatchery program as well as the annual incidence of natural spawning by hatchery-origin fish and to complete comprehensive assessments of hatchery action effectiveness at 6-year intervals. Specific criteria for each program are to be developed in Hatchery and Genetic Management Plans.

- **Ecological Interactions**. The strategy for ecological interactions includes monitoring the effectiveness of actions addressing non-native species and predation by northern pikeminnow, marine mammals, and birds and developing 6-year summary evaluations.

- **Mainstem/Estuary.** The LCFRB RME program cites the estuary RME program developed by Johnson et al. to provide status monitoring, action effectiveness monitoring, and uncertainties research.

#### *10.3.1.5 Research Needs*

The LCFRB RME program identifies specific research needs for salmon population status, stream habitat and watershed health, hydropower, fisheries, hatcheries, ecological interactions, and the mainstem/estuary.

#### *10.3.1.6 Data Management*

The LCFRB RME program identifies a need for a data management needs assessment. It also notes the need to develop and maintain regionally standardized datasets and a data storage and management system, along with a need to produce and distribute regular progress reports and coordinate with other Columbia Basin efforts.

#### *10.3.1.7 Programmatic Evaluation*

The LCFRB RME program makes recommendations for programmatic evaluation, or adaptive management.

### 10.3.2 Oregon Management Unit

The Oregon management unit plan also contains a chapter devoted to research, monitoring, and evaluation (see ODFW 2010, Chapter 8). This chapter outlines the research, monitoring, and evaluation needs of the plan as they pertain to biological criteria (i.e., population VSP parameters) and threats (as organized under the ESA listing factors). It also describes how Oregon will incorporate RME into an adaptive management framework. The ODFW monitoring plan is based closely on the NMFS (2007) guidance document. It is organized around the key questions, as identified in the NMFS document, that must be answered for delisting decisions. It also includes the analytical framework Oregon intends to use to answer those key questions, along with measurable criteria against which the state intends to measure progress toward those goals. Like the LCFRB plan, the ODFW plan addresses status and trend monitoring, implementation monitoring, effectiveness monitoring, and critical uncertainty research.

#### *10.3.2.1 Biological Status Monitoring*

The Oregon management unit plan describes biological status monitoring needs for population abundance, productivity, spatial structure, and diversity. Included are decisions and key questions for evaluating population status as it pertains to each of the four VSP parameters, as well as analytical guidelines and measurable criteria. In general, decisions and key questions are derived from TRT documents and the Oregon management unit plan. The plan identifies a need for annual benchmarks of abundance and productivity based on annual, scaled estimates of spawner abundance, harvest of natural-origin fish, age at return, and an index of climate impact. The plan proposes to develop these annual estimates through spatially balanced, random surveys based on the generalized random tessellation stratified (GRTS) technique and using field protocols developed by ODFW.

For spatial structure, the plan identifies a need for annual estimates of the distribution and density of natural-origin spawning adults for each population (and for annual monitoring of juveniles at the stratum scale), as well as for 5-year assessments of habitat conditions throughout the accessible distribution of each population. The plan proposes spatially balanced, random surveys based on the GRTS technique and using ODFW protocols to obtain these estimates. In addition, the plan identifies a need for annual monitoring of streamflow.

For diversity, the plan identifies a need for periodic monitoring of key life history characteristics of each population; annual monitoring of spatial distribution, abundance, and origin of adult spawners in each population; hatchery monitoring; genetic marker monitoring; and periodic assessment of habitat diversity, occupancy, and anthropogenic changes to habitat and the environment.

The plan also calls for fish-in/fish-out (i.e., life-cycle) monitoring in at least one subwatershed in each stratum to provide marine survival estimates and another view of freshwater survival and productivity.

The plan describes a strategic approach to biological status monitoring that includes: (1) documenting the precision and bias associated with various monitoring protocols, (2) implementing GRTS or census-based spawning surveys where possible and using adult trapping facilities where necessary to provide population-level information on VSP parameters, and (3) using GRTS surveys to provide stratum-level information on juvenile abundance and, in at least one subwatershed, monitoring (via traps) adults in/juveniles out to provide an estimate of freshwater productivity. The chapter also describes how ODFW will prioritize resources under limited or fluctuating funding scenarios, including populations that will be cut from RME when resources are inadequate.

#### *10.3.2.2 Monitoring Related to Listing Factors*

The Oregon management unit plan discusses monitoring needs related to threats as organized under the five ESA listing factors. For each listing factor, the plan identifies the decision and key questions for delisting and status assessment (based on the NMFS 2007 guidance document) and discusses monitoring needs for status and trends, action effectiveness, and implementation. Discussion of status and trend monitoring includes identification of measurable criteria (metrics and evaluation thresholds), analytical procedures, and specific RME needs.

- **Habitat.** For habitat status and trend monitoring, the plan identifies a need for 5-year estimates of the spatial pattern and status of specific habitat attributes for each population as well as annual assessments of the status and spatial pattern of water quality for each population. The plan calls for these to be determined using spatially balanced, random surveys based on the GRTS technique and using ODFW or Oregon Department of Environmental Quality protocols. The plan also identifies the need for annual assessments of the status and spatial pattern of streamflow for each population.

  In addition to this 5-year monitoring, the plan calls for annual assessments at the stratum scale. Annual assessments are conducted during the summer; after 5 years, they provide a dense enough sample to characterize summer habitat conditions by population. This information complements the 5-year surveys, which are conducted in winter to characterize conditions during that season.

  For habitat implementation and compliance monitoring, the plan notes the needs for annual assessments of (1) compliance with existing habitat protection rules and regulations, (2) implementation of habitat best management practices, and

(3) implementation of habitat recovery actions. For habitat action effectiveness monitoring, the plan advocates use of intensively monitored watersheds (IMWs) as well as site-specific monitoring of habitat protection and BMPs and habitat restoration actions.

- **Hydropower.** For hydropower-related monitoring, the plan generally defers to the Clackamas River Hydroelectric Project Fish Passage and Protection Plan (Portland General Electric Company, 2006). Analytical procedures and RME needs for Laurance Lake Dam are to be determined.[3]

- **Harvest.** For monitoring related to the impacts of harvest, the plan identifies the need for annual estimates of mortality that is due to harvest for each population and annual estimates of the marine survival rates of natural-origin coho salmon (by monitoring adults in and smolts out of one intensively monitored watershed per stratum). For harvest implementation and compliance monitoring, the plan identifies a need for annual estimates of mortality, and for evaluation of whether managers meet targets for implementing mark-selective Chinook salmon fisheries and for shifting spring Chinook salmon commercial and tribal harvest to terminal areas during low-return years. For effectiveness monitoring related to harvest, the plan identifies a need to conduct studies to assess the effectiveness of harvest management actions needed to achieve harvest impact goals.

- **Hatcheries.** For status and trend monitoring related to hatcheries, the plan identifies the need for annual assessments of the abundance, distribution, and origin of hatchery fish spawning in each population, annual monitoring of the spatial and temporal distribution of juvenile fish released by hatchery programs, and all of the status and trend monitoring described for fish abundance and productivity. The plan also describes the need for monitoring and documentation that demonstrate that HGMPs have been implemented and effective.

- **Disease/predation**. For status and trends related to predation (by Caspian terns, double-crested cormorants, marine mammals, and northern pikeminnow), the plan identifies a need for monitoring of predation associated with anthropogenic alterations in the Columbia River estuary, at Bonneville Dam, and in Bonneville Reservoir. For issues related to disease, the plan calls for sampling of natural populations in and near hatcheries to determine occurrence of pathogens that may cause disease. The plan also calls for watershed-scale sampling for the occurrence of invasive aquatic species known to affect salmon and steelhead. Implementation and compliance monitoring and effectiveness monitoring needs for predation and disease are to be determined.

- **Regulatory mechanisms.** For monitoring related to regulatory mechanisms, the plan describes the need for a system that tracks whether regulatory actions called for in the plan are being implemented. It also identifies a need for a randomized sampling program to test whether permits issued under regulatory programs

[3] Monitoring of hydropower-related facilities in the Sandy and Hood subbasins was not addressed because the dams have been removed.

designed to protect riparian and instream habitat are being issued as designed and being enforced.

The plan also identifies specific critical uncertainties for each of the VSP parameters and for each of the listing factors and includes an appendix describing existing monitoring programs (see ODFW 2010, Appendix J).

Like the LCFRB plan, the Oregon management unit plan discusses the need for and benefits of integrating monitoring plans throughout the region. As a step toward such integration, the plan advocates development of a survey design process that promotes data sharing, agreement on a core set of monitoring questions, coordination of monitoring activities, and development either of common protocols and methods or of ways to "crosswalk" data derived from different protocols. The plan also notes the need for improved data management and access through development of distributed data systems and data management infrastructure.

### 10.3.3 White Salmon Management Unit

The White Salmon management unit plan (NMFS 2013) contains a brief discussion of monitoring, intended to provide a framework for the development of a detailed RME plan for the White Salmon, and identifies several critical uncertainties and actions needed to address them.[4] The management unit plan also notes that various monitoring efforts are under way and that there is a need for a coordinated monitoring program, and it includes some notes on initial steps in designing such a program. It also discusses adaptive management in general, identifies in-basin and out-of-subbasin research needs, discusses the various types of monitoring needed (implementation, status/trend, effectiveness), and the need for consistency/coordination with other monitoring programs. The plan also notes that the reintroduction plan for White Salmon River salmon will rely heavily on results of research and be guided by ongoing monitoring and evaluation.

## 10.4 Estuary Module RME

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) also includes a chapter that describes RME needed to assess juvenile salmonid performance in the estuary and to evaluate the effectiveness of the 23 management actions described in the module. Like the management unit RME plans, this chapter notes the need for various types of monitoring (status and trends, action effectiveness research, critical uncertainties research, implementation and compliance monitoring) and for an adaptive management approach. It also discusses the need for coordination of monitoring efforts and for data and information management, synthesis, reporting, and evaluation. The estuary module RME chapter identifies RME needs associated with each management action in the module; describes existing monitoring plans, programs, and projects that relate to those needs; and identifies gaps and potential projects to fill those gaps.

[4] PacifiCorp breached Condit Dam in October 2011 and completely removed the dam in September 2012. Specific actions to improve habitat and monitor results will be determined once post-removal habitat conditions have been evaluated.

Monitoring for the estuary module will build on ongoing efforts, particularly efforts established under the *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program* (ERME) (Johnson et al. 2008). The ERME monitoring plan forms the basis for estuary RME in the 2008 Federal Columbia River Power System Biological Opinion (NMFS 2008f) and the 2010 FCRPS Supplemental Biological Opinion (NMFS 2010a).

In addition to the ERME plan, other monitoring plans and guidance documents applicable to estuary RME are listed in the module. To implement these existing monitoring plans, a number of monitoring programs and projects are already under way in the estuary. The module identifies these programs and projects and relates them to the RME needs for each of the 23 management actions in the module, identifies a number of gaps, and suggests projects to fill those gaps. For each monitoring need, the module also recommends sampling design, spatial and temporal scale, variables to be measured, measurement protocols, variables to be derived, analyses needed, and possible implementing and funding entities.

As implementation of monitoring programs proceeds in the estuary and tributaries, there will be a need to ensure appropriate integration. For example, are monitoring designs compatible and/or comparable, are methods compatible or comparable, and are RME efforts addressing recovery plan questions?

## 10.5 RME in Biological Opinions and Records of Decision

Several federal agencies have natural resource responsibilities related to the ESA and rely on biological opinions and issue records of decision that include RME that may be relevant to salmon recovery. Efforts to develop and coordinate recovery plan monitoring in the Lower Columbia subdomain should consider how RME needs and recommendations outlined in such documents could help fulfill recovery plan monitoring needs. Similarly, in proposing RME activities in biological assessments and records of decision, federal agencies should consider the context of recovery plan monitoring needs.

Examples of relevant biological opinions include those for Federal Energy Regulatory Commission relicensing settlement agreements, harvest management decisions, and habitat actions, particularly large-scale actions. The 2008 Federal Columbia River Power System Biological Opinion and its 2010 Supplement, including the FCRPS Adaptive Management Implementation Plan (AMIP) (NMFS 2009c), along with associated RME work groups, are also relevant in the Lower Columbia, although less so than in the interior of the Columbia Basin.

## 10.6 Regional Coordination Efforts

Described briefly below are some of the regional entities that serve as a catalyst or provide forums for regional coordination of monitoring efforts. Such coordination efforts take place within the context of the RME guidance documents described above, in Section 10.2, and the management unit RME plans described above, in Section 10.3:

- **The Bonneville Power Administration and Northwest Power and Conservation Council**. The Bonneville Power Administration (BPA) is a major funding source for salmon recovery projects in the Columbia Basin as part of its obligation to mitigate the effects of the operation of the FCRPS on fish and wildlife. The Northwest Power and Conservation Council (NPCC) plays an important role in deciding which projects BPA should fund. As such, these two organizations function as coordinators of RME, both in terms of the RME actions they fund and the information-sharing processes they initiate or approve. For more information, see http://efw.bpa.gov/IntegratedFWP/anadfishresearch.aspx and http://www.nwcouncil.org/fw/.

- **The Columbia Basin Fish and Wildlife Authority**. The Columbia Basin Fish and Wildlife Authority (CBFWA) provides a venue for representatives of the states and tribes to work toward comprehensive and effective planning and implementation of fish and wildlife programs in the Columbia Basin. CBFWA's role includes evaluating monitoring needs and making recommendations to the NPCC and BPA on project funding. CBFWA is also a central source for information and news on status and trends of fish and wildlife in the Columbia Basin. For more information, see http://www.cbfwa.org/index.cfm.

- **The Pacific Northwest Aquatic Monitoring Partnership**. The Pacific Northwest Aquatic Monitoring Partnership (PNAMP) is a coordinating forum whose primary mission is to encourage standardization of monitoring methods among state, federal, and tribal aquatic habitat and salmonid monitoring programs. PNAMP partners strive to improve communication and sharing of resources and data, and they work toward compatible monitoring efforts that will ultimately provide increased scientific credibility, cost-effective use of limited funds, and greater accountability to stakeholders. They develop and advance recommendations for consideration and potential adoption by participating agencies. The PNAMP effort is funded by in-kind services and modest funding from various agencies. A PNAMP demonstration project on Integrated Status and Trends Monitoring is under way in the Lower Columbia subdomain. For more information, see http://www.pnamp.org/.

- **Integrated Status and Effectiveness Monitoring Program**. The Integrated Status and Effectiveness Monitoring Program (ISEMP) is a scientific group working on four intensively monitored watersheds to test and evaluate methods for status and trends monitoring and effectiveness monitoring. It is hoped that the group's results will help others choose and design monitoring programs more effectively. For more information, see http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/index.cfm.

- **FCRPS Biological Opinion Work Groups**. As noted above (in Section 10.2.3.2), completion of the 2008 Biological Opinion on the operation of the Federal Columbia River Power System (FCRPS) stimulated collaboration related to RME in the Columbia Basin, including the mainstem lower Columbia River and estuary. FCRPS Biological Opinion work groups were formed and tasked with determining how best to implement the recommendations in the Biological Opinion and how to conduct related RME. These groups provide wide-reaching catalysts for RME

coordination. Because these work groups are ongoing and are evaluating agency proposals for funding, they may create the impetus for future coordination of activities for the Lower Columbia subdomain.

One effort that grew out of this coordination was the Anadromous Salmonid Monitoring Strategy (ASMS). The ASMS was a collaborative process in which Columbia Basin fish management agencies and tribes had an opportunity to react to work group recommendations from the Bonneville Power Administration, U.S. Army Corps of Engineers, U.S. Bureau of Reclamation, and other state and federal agencies that monitor anadromous salmonids and/or their habitat. This interaction led to consensus on monitoring approaches.

Of the above coordination efforts, the Anadromous Salmonid Monitoring Strategy and PNAMP Integrated Status and Trends Monitoring Demonstration Project are particularly relevant in the Lower Columbia recovery subdomain. They are described in more detail below.

### 10.6.1 Anadromous Salmonid Monitoring Strategy (ASMS)

The Anadromous Salmonid Monitoring Strategy (ASMS) grew out of the Columbia Basin Coordinated Anadromous Monitoring Workshop, which BPA, CBFWA, NMFS, and the NPCC convened in Skamania, Washington, in October and November 2009. The purposes of the workshop were to develop a coordinated anadromous fish monitoring strategy for the Columbia Basin, to reach agreement among participants on an efficient and effective framework for monitoring, and to outline a specific implementation strategy.

The focus of the workshop was the monitoring of population status and trends using VSP criteria, of habitat action effectiveness, and of salmon hatchery effectiveness. Attendees used general guidelines for monitoring study design and for quality standards in each of these topics (primarily these guidelines were drawn from the Crawford and Rumsey [2011] RME guidance document) and collaborated to develop a monitoring strategy for each of four regions within the Columbia Basin, including the Lower Columbia region. In developing the strategies, participants evaluated inventories of all current monitoring work and identified overlaps and gaps for VSP, habitat effectiveness, and hatchery effectiveness data. From these inventories and evaluations, they developed a final, prioritized strategy. The framework and strategy are intended to address the needs of the NPCC's Fish and Wildlife Program and the 2008 FCRPS Biological Opinion and its 2010 Supplement and to contribute to ESA recovery plan and other regional fisheries management monitoring needs.

The ASMS (available at http://www.cbfwa.org/AMS/FinalDocs.cfm) contains the following elements relevant to the Lower Columbia subdomain:

- Lower Columbia subregion monitoring strategy
- Populations targeted for habitat status and trend and fish-in/fish-out monitoring, which will be used to assess habitat action effectiveness

- Critical monitoring projects, monitoring strategy, prioritized monitoring gaps, recommendations for addressing monitoring gaps under the FCRPS Reasonable and Prudent Alternative (RPA), prioritized projects (as of 2009) to be continued as-is or with modifications, and new funding proposals and estimated costs to address monitoring gaps

Co-managers subscribing to this strategy include the Oregon Department of Fish and Wildlife and the Washington Department of Fish and Wildlife. The Lower Columbia Fish Recovery Board also participated in the discussions and subscribes to the strategy. The ASMS products helped to identify gaps in population-scale adult abundance and smolt monitoring in the Lower Columbia subdomain and to obtain funding to fill those gaps. Additional effort, coordination, and funding will be needed to complete a comprehensive monitoring program for the Lower Columbia subdomain that includes the full range of monitoring needed for this recovery plan (e.g., monitoring of population-level spatial structure and diversity, monitoring of habitat status and trends at various scales, and action effectiveness monitoring).

The general ASMS approach for the Lower Columbia subdomain is as follows:

- **Viable salmonid population criteria:** Conduct annual surveys of natural- and hatchery-origin spawner abundance at the population scale to facilitate assessment of productivity, diversity, and distribution. Conduct annual surveys of juvenile density and distribution at the stratum scale; conduct life cycle (fish-in/fish-out) monitoring in at least one subwatershed per stratum.

- **Habitat:** Conduct annual generalized random tessellation stratified (GRTS)-based habitat surveys at the stratum scale; do pre- and post monitoring at habitat restoration sites, and use intensively monitored watersheds. (An intensively monitored watershed was initiated in the Mill/Abernathy/Germany subbasin of the Lower Columbia subdomain in 2003 with funds from NMFS and the Washington Salmon Recovery Funding Board. For the IMW to be effective in meeting its goals, funding should be maintained for monitoring and for implementation of restoration treatments of sufficient scope and intensity to provide detectable fish and habitat responses.

- **Hatchery effectiveness:** Monitor the effects of segregated and integrated hatchery programs, the coded-wire tag program, relative reproductive success, natural- and hatchery-origin spawner abundance, and residualism/ecological interactions.

WDFW and ODFW currently use slightly different approaches to monitor VSP criteria, particularly adult abundance. WDFW estimates of adult abundance have been based on expansions from fish surveys or redd counts combined with mark-recapture studies or from monitoring at weirs. In most cases ODFW's current redd surveys are GRTS-based, which facilitates evaluation of the precision and certainty of the adult abundance estimates. Both agencies are working through the PNAMP Integrated Status and Trends Monitoring program (see below) to improve integration of existing and new monitoring efforts for status and trends.

### 10.6.2 PNAMP Integrated Status and Trend Monitoring Demonstration Project

The Pacific Northwest Aquatic Monitoring Partnership's (PNAMP) Integrated Status and Trend Monitoring (ISTM) project is intended to demonstrate approaches for and the utility of integrating the collection of information to address multi-scale questions about the status and trends of fish (ESA-listed salmon, steelhead, and, potentially, bull trout), and physical, chemical, and biological attributes in stream networks. The overall intent is to assist PNAMP's participating members in developing strategic action plans for monitoring in the bi-state lower Columbia River demonstration area, as well as to demonstrate the general approach to developing such plans for other areas in the Pacific Northwest. The ISTM effort will provide entities tasked with monitoring fish populations and aquatic habitat in the Pacific Northwest with a roadmap for integration of scientifically sound monitoring programs intended to meet the needs of decision makers and managers. Specifically, the ISTM project will apply this approach and develop recommendations for integrated monitoring plans for ESA-listed salmon and steelhead and their habitats in the Lower Columbia subdomain.

A major objective of the ISTM project is to apply a "master sample" concept to the selection of sampling locations in the Lower Columbia subdomain. The project is being accomplished using a collaborative approach that involves PNAMP members and other local partners, including LCFRB, WDFW, and ODFW, who plan to use the resulting monitoring designs in the implementation of their RME plans. The master sample concept, along with other monitoring and monitoring design tools, has broad applicability to address status and trends questions in the estuarine and near-shore marine areas (area-based master sample), in addition to the status and trends of attributes along linear stream networks.

Other goals of the program include the following:

- Develop a coordinated VSP monitoring program that addresses key regional monitoring questions in a study design of sufficient quality and quantity to determine the status of Lower Columbia River salmon and steelhead.
- Develop a habitat status and trends monitoring design for the Lower Columbia subdomain.
- Identify and prioritize decisions, questions, and objectives.
- Evaluate the extent to which existing programs align with these decisions, questions, and objectives.
- Identify the most appropriate monitoring design to inform priority decisions.
- Use trade-off analysis to develop specific recommendations for monitoring.
- Recommend implementation and reporting mechanisms.

## 10.7 Additional Needs for RME in the Lower Columbia

Continued challenges in the Lower Columbia subdomain relate to efforts to develop an integrated, comprehensive RME system for the subdomain that is consistent with

recovery plan needs and efforts to design data management and integration systems. There is also a need for funding to adequately implement the RME recommendations of the management unit recovery plans.

### 10.7.1 Integrated RME Program

The overall challenge in the Lower Columbia subdomain is to continue the process begun by CBFWA and NMFS in 2009 to integrate and coordinate the many RME efforts under way and to develop a systematically designed regional RME program. Such a program will help ensure that we have the information needed to assess salmon and steelhead status and the status of habitat and other threats and to ensure that we are using resources appropriately and efficiently. Such integration and coordination efforts should occur within the context of the full range of monitoring needs identified in recovery plans.

### 10.7.2 Data Management and Integration

Data management and integration also continue to pose challenges in the Lower Columbia subdomain and entire Columbia Basin. Through CBFWA, a collaborative effort is under way to develop assessment and data sharing strategies for meeting regional reporting requirements within each subregion of the ASMS. This effort will also identify gaps in data management and sharing capacities and establish strategies to close those gaps. This effort will address key questions such as how data will be shared, which data dictionary will be used, and what mechanisms will be developed to ensure that consistent evaluations, calculations, and metadata are used and documented (Columbia Basin Fish and Wildlife Authority 2010).

Such a strategy is needed to ensure effective evaluation of the FCRPS Biological Opinion, effective evaluation of recovery plan implementation and progress toward the recovery of ESA-listed salmon and steelhead, and effective implementation of the anadromous salmonid elements of the Columbia River Basin Fish and Wildlife Program. If successful, this data sharing strategy will provide the framework and technical tools to allow data sharing across disparate systems from the local level to the regional level; it also will ensure that comparable data from different sources can be combined to facilitate assessment at the regional scale.

## 10.8 Research on Critical Uncertainties

As noted in Section 10.3, the management unit recovery plans have identified comprehensive lists of critical uncertainties and research, monitoring, and evaluation needs. The White Salmon and Washington management unit plans have discrete sections on critical uncertainties for all of the ESUs in general (see Section 8.3 of NMFS 2013, pp. 8-4 through 8-6, and Section 9.6 of LCFRB 2010a, pp. 9-68 through 9-73), while the Oregon management unit plan embeds relevant critical uncertainties within subsections on monitoring and evaluation needs related to the four VSP parameters and five ESA listing factors (see Sections 8.4 and 8.5, respectively, of ODFW 2010). In addition, in June 2010, the Lower Columbia Fish Recovery Board completed the *Research, Monitoring, and Evaluation Program for Lower Columbia Salmon and Steelhead* as a

companion to its recovery plan (LCFRB 2010b). This document also describes critical uncertainties.

The species chapters of this recovery plan contain preliminary lists of priority critical uncertainties for each species (see Sections 6.6.8, 7.4.3.8, 7.5.3.8, 7.6.3.6, 8.6.8, and 9.6.7). These preliminary priorities were identified by Oregon and Washington recovery planners and NMFS Northwest Regional Office and Northwest Fisheries Science Center staff during a November 2010 workshop. They are preliminary priorities only (and are not in ranked order); additional discussion among local recovery planners and NMFS staff will be needed to finalize future research and monitoring priorities for Lower Columbia River salmon and steelhead. NMFS expects to work with management unit recovery planners to finalize research and monitoring priorities and to ensure that results are incorporated into future 5-year reviews (see Section 10.9).

The work in the management unit plans and the preliminary priorities identified in this recovery plan will provide the basis for continuing discussion of how to prioritize funds and activities for monitoring and research in the lower Columbia Basin.

## 10.9 RME and ESA 5-Year Reviews

The ESA requires NMFS to assess the status of listed species every 5 years. NMFS completed the most recent 5-year review in 2011 (76 *Federal Register* 50448, NMFS 2011b). NMFS will work with recovery plan implementers and other entities to link prioritization of RME efforts to products that will inform these 5-year reviews in the future.

The Oregon, Washington, and White Salmon management unit plans identify initial monitoring and evaluation actions intended to produce information needed to further refine particular strategies or to validate key assumptions behind recovery objectives. For example, the Oregon management unit plan (ODFW 2010) highlights key uncertainties regarding historical and current population structure in the Gorge strata and calls for additional analysis to refine the identification of historical population structure by the WLC TRT. The White Salmon management unit plan (NMFS 2013) highlights the need for an immediate monitoring effort to evaluate fish recolonization above the former Condit Dam site. Both the Oregon and Washington management unit plans call for a review of methods for assessing population status with the intent of improving the methods to ensure that progress toward recovery objectives can be effectively evaluated. The Oregon and Washington management unit plans also both call for developing—and periodically reviewing and updating—implementation plans for recovery actions (including RME). NMFS anticipates working with the parties involved in these efforts to prioritize and set timelines for these RME tasks to ensure that information is developed and made available for consideration during future 5-year reviews.

# 11. Implementation and Coordination

Recovery plan implementation involves many entities and stakeholders, and the needs for coordination are complex and occur at multiple levels. For instance, implementation and coordination needs exist at the management unit and subdomain levels and involve government entities at the federal, state, tribal, and local levels and also non-governmental entities. Coordination at the subdomain level is further complicated by the bi-state nature of the Lower Columbia subdomain, the need for coordination on issues of regional scope, and the need for close coordination with implementers of estuary recovery actions.

Coordination needs may differ depending on the type and scale of action in question. For instance, habitat actions require extensive local coordination but also coordination at the ESU or DPS level to ensure that overall recovery needs are being met. Similarly, although many funding decisions are made locally, there is a need for coordination of funding sources at the subdomain scale to ensure the most effective use of limited funds. Recovery strategies and actions related to harvest and hatcheries are another example of actions that require coordination at both state and subdomain scales and with NMFS and other entities.

In general, the management unit plans are the primary documents guiding implementation in the Lower Columbia subdomain. Coordination at the subdomain scale will occur as needed and will be achieved primarily through the Lower Columbia Recovery Plan Implementation Steering Committee, which will be the successor to the Lower Columbia Recovery Planning Steering Committee, which NMFS convened to guide development of this recovery plan and which will continue on to coordinate implementation.

This chapter presents NMFS' vision for recovery plan implementation, defines implementation responsibilities for NMFS and the management units, and describes how implementation of this recovery plan will be structured and coordinated.

## 11.1 NMFS' Vision for Recovery Implementation

In general, NMFS' vision for recovery implementation is that recovery plan actions are carried out in a cooperative and collaborative manner so that recovery and delisting occur (NMFS 2008d). NMFS' strategic goals to achieve that vision are as follows:

- Sustain local support and momentum for recovery implementation.
- Implement recovery plan actions within the time periods specified in each plan.
- Encourage others to use their authorities to implement recovery plan actions.
- Ensure that the implemented actions contribute to recovery.
- Provide accurate assessments of species status and trends, limiting factors, and threats.

NMFS' approach to achieving these goals is as follows:

- Support local efforts by using domain teams to coordinate internally and externally and encourage recovery plan implementation.[1]
- Use recovery plans to guide regulatory decision making.
- Provide leadership in regional forums to develop research, monitoring, and evaluation processes that track recovery action effectiveness and status and trends at the population and ESU levels.
- Provide periodic reports on species status and trends, limiting factors, threats, and plan implementation status.
- Staff and support the Lower Columbia Recovery Plan Implementation Steering Committee

NMFS will carry out its vision, goals, and strategic approach to recovery for the Lower Columbia River ESUs and DPS by working in partnership with the Lower Columbia Recovery Plan Implementation Steering Committee and the management units.

## 11.2 Prioritizing Recovery Actions

Prioritizing recovery actions is an important part of implementation of this recovery plan. Although the management unit plans establish population priorities and in some cases identify specific sites or reaches for implementation of tributary habitat actions, additional prioritization work is needed at both the management unit and subdomain levels, both within and among threat categories. The sections below describe how the management unit plans approached questions of prioritization and offer perspectives for potential consideration during implementation of the recovery plan.

### 11.2.1 Prioritizing Populations

As described in Section 3.1.3, management unit recovery planners developed a recovery scenario for each ESU that designates individual population goals at three levels of contribution to recovery: primary, contributing, and stabilizing. Populations designated as primary need to be restored to viability and are in many ways the foundation for ESU recovery. It is likely that primary populations will be prioritized for implementation of recovery actions, and actions benefitting multiple primary populations may be given highest priority. However, the management unit plans are clear that no population is unimportant to recovery. Regardless of whether a population is designated as primary, contributing, or stabilizing, it must achieve the status designated in the recovery scenario if the ESU as a whole is to recover. Recovery actions will be needed even for those populations designated as stabilizing, to maintain them at their baseline persistence probability.

[1] Domain teams are an organizational structure internal to NMFS whose purpose is to coordinate recovery plan completion and implementation. The teams promote consistency in internal decision making and work with federal, state, tribal, and local recovery parties to achieve recovery plan objectives.

### 11.2.2 Geographic Priorities

Establishing priorities at the stream reach scale is useful in identifying and sequencing habitat protection and restoration measures. All of the management unit plans identify site-specific tributary habitat actions for recovery. The Washington management unit plan prioritized tributary habitat actions by stream reach based on the needs of all salmon and steelhead populations, collectively, within a particular subbasin. The Oregon management unit plan did some population-specific prioritization based on where an action will have the greatest beneficial effect and where implementation is most feasible, but for many Oregon subbasin additional assessment is needed to determine protection and restoration priorities at a meaningful spatial scale (ODFW 2010). The White Salmon also identifies areas as a high priority for habitat actions but points to the need for additional information to identify and prioritize specific habitat actions (NMFS 2013). In each case, the priority sites or reaches within each subbasin are not ranked against each other; rather, the management unit plans considered them to together be the highest priority areas for implementation of tributary habitat actions within each subbasin.

Oregon recovery planners determined locations for tributary habitat actions based on reach-scale habitat assessments or, when assessments were unavailable, professional judgment (ODFW 2010). For salmon and steelhead populations in subbasins that lack a reach-scale habitat assessment, the Oregon management unit plan recommends that an assessment be conducted to better define the highest priority areas for implementation of recovery actions (ODFW 2010).

Washington recovery planners used habitat assessment and modeling tools to assess the significance of each stream reach to net production of an individual species within a subbasin.[2] From this assessment, recovery planners identified high-, medium-, and low-priority reaches for each species and then placed reaches into one of four tiers, taking into consideration both the relative importance of a reach within a population and each fish population's importance relative to regional recovery objectives (LCFRB 2010a). This process yielded a four-tier, multi-species prioritization of stream reaches within each subbasin.

The White Salmon management unit plan identifies specific areas as high-priority reaches for habitat protection and restoration based on the expected distribution of salmon and steelhead species within the subbasin. Priority reaches were determined using information from current literature (NMFS 2013).

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) identifies priority reaches for each management action it analyzes (see Table 5-6 of NMFS 2011a). However, the estuary module refrains from explicitly prioritizing actions because it considers all of the management actions it identifies as important in improving the survival of juvenile salmonids in the Columbia River estuary and plume. The module does identify actions likely to be most beneficial to stream-type and ocean-type salmonids and actions that are most cost-effective (see Tables 7-2, 7-3, and 7-5 of NMFS 2011a); these analyses take into account the probable implementation constraints

[2] For more detail, see p. 3-30 of LCFRB (2010a).

for each action. The module also notes that a logical first step in implementation would be a conversation among all relevant entities and stakeholders to discuss near-term implementation priorities, with a goal of developing a 5-year implementation plan that provides specificity and certainty regarding near-term actions and that identifies lead entities for implementation of specific actions or projects.

### 11.2.3 Prioritizing Actions

Because the Oregon and Washington management unit plans consider all of the actions they identify as significant for recovery and thus a high priority,[3] they defer detailed prioritization of actions to the implementation phase of recovery. Many decisions about prioritization will be made in the process of developing implementation schedules (see Section 11.3.2). For Oregon populations, an implementation team is expected to develop 3-year implementation schedules that outline priorities for the upcoming years; implementing entities then will use the action priorities outlined in the implementation schedules to identify projects for implementation and seek funding for those projects (ODFW 2010). Similarly, high-priority actions for Washington populations will be identified in a series of 6-year implementation work schedules that will include schedules, costs, and constraints and identify responsibilities. The Lower Columbia Fish Recovery Board, working with a steering committee, will facilitate and coordinate efforts among oversight and implementing partners; this will include setting priorities (LCFRB 2010a). The Washington management unit plan notes that priorities are expected to evolve over time based on new information, progress in implementation, and the adaptive management process.

Both the Oregon and White Salmon management unit plans offer some guidance on how actions might be prioritized, either during the implementation phase or as an aid in identifying actions that need to be implemented immediately to reduce near-term risks. The White Salmon management unit plan recommends that projects be prioritized for funding based on a balance of biological benefit, cost, and feasibility of implementation, with the highest funding priority given to projects that address primary limiting factors, have high biological benefit, are relatively inexpensive, and are feasible (NMFS 2013). The Oregon management unit plan suggests that the following be considered high priorities as actions are identified for implementation and funding:

- Actions for populations that must achieve viability status (i.e., primary populations, which are targeted for high or very high persistence priority)
- Actions that address a threat reduction need
- Actions that address a primary limiting factor
- Actions that address a relatively large gap between baseline and target status, or that address a relatively large threat reduction need
- Actions in locations that will result in or protect accessible and connected high-quality habitat

[3] See p. 388 of ODFW (2010) and p. 69 of the overview to LCFRB (2010).

- Restoration actions in high intrinsic potential (IP) locations[4]
- Actions intended to protect threatened high-quality or highly productive habitat
- Actions that provide resiliency against climate change
- Actions in areas that are believed to result in a significant improvement in survival
- Actions that address those threat categories that require the most improvement[5]

For more discussion of prioritization of actions, see p. 387 of ODFW (2010).

The Washington management unit plan does not explicitly address prioritization of actions across threat categories.

## 11.3 Organizational Structure and Implementation Roles and Responsibilities

Effectively implementing recovery actions for Lower Columbia River Chinook and coho salmon, Lower Columbia River steelhead, and Columbia River chum salmon will require coordinating the actions of diverse private, local, state, tribal, and federal parties across two states. Coordination needs within the Lower Columbia subdomain exist at multiple levels. At the subdomain level, the Lower Columbia Recovery Plan Implementation Steering Committee (LC Steering Committee) will lead efforts to coordinate the actions of these many players, working with subcommittees and other regional forums as needed. At the management unit level, Washington's Lower Columbia Fish Recovery Board will lead implementation in the Washington management unit and the Oregon Department of Fish and Wildlife implementation coordinator and stakeholder team will lead recovery plan implementation in Oregon, supported by the governance structure of the Oregon Plan for Salmon and Watersheds. In the White Salmon subbasin, the Washington Gorge Implementation Team, coordinated by NMFS, currently is tracking progress on implementation of the White Salmon management unit plan (NMFS 2013) and will also coordinate among the multiple entities involved in implementation there. Members of the Washington Gorge Implementation Team include the Yakama Nation, state and local agencies, local conservation districts, and other entities.

Because the planning areas of the Washington and Oregon management units overlap in tidal portions of tributaries with the planning area of the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a), there is also a need for coordination between the management units and entities implementing estuary recovery actions. Finally, NMFS has a unique role in recovery plan implementation. These various coordinating forums and roles are described below.

[4] See ODFW (2010) p. 205, Table 6-39, for a description of high intrinsic potential areas.
[5] This is the only specific guidance in the management unit plans regarding prioritization of actions across the threat categories.

### 11.3.1 Subdomain Level: Lower Columbia Recovery Plan Implementation Steering Committee

The Lower Columbia Recovery Plan Implementation Steering Committee (LC Steering Committee) will serve as a forum for communication and coordination on a bi-state level, among management units, with entities implementing estuary recovery actions, and with other regional forums. Figure 11-1 shows the makeup of the steering committee and its relationship to other regional entities.

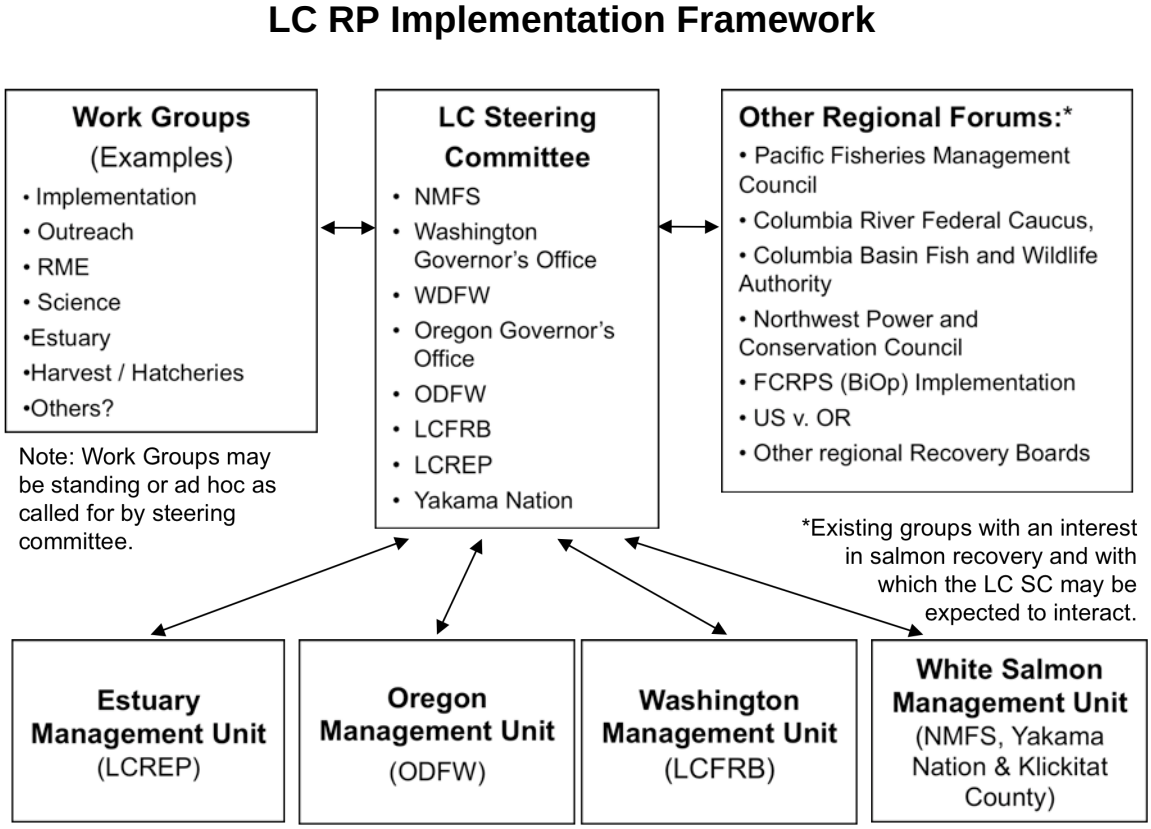


**Figure 11-1.** *Lower Columbia Recovery Plan Implementation Organizational Structure*

Functions of the steering committee include the following:

- Facilitating communication and coordination between states and among management units on issues related to implementation of recovery actions
- Facilitating communication and coordination with other regional entities and forums on issues related to implementation of recovery actions
- Increasing awareness of the recovery plan and advocating for implementation of recovery actions
- Providing recommendations for prioritization of recovery efforts and the use of resources
- Advancing the application of adaptive management to recovery efforts and the coordination of RME efforts

- Identifying and coordinating funding opportunities for recovery actions and RME
- Convening and overseeing issue-specific work groups as needed
- Providing an interface with the Recovery Implementation Science Team convened by NMFS

The committee will also serve as a link to other regional forums that have an interest in salmon recovery, such as the Northwest Power and Conservation Council, Columbia Basin Federal Caucus, Pacific Fisheries Management Council, and Columbia Basin Fish and Wildlife Authority.

A key related program is implementation of the Northwest Power and Conservation Council's Fish and Wildlife Program subbasin management plans. NMFS, in full coordination with management unit leads, fishery management agencies, and tribes, should ensure that the project selection process for the NPCC's subbasin plans within the management unit is consistent with the ESA priority actions in this recovery plan and the implementation schedules. The steering committee may serve as a coordinating forum for this effort.

#### *11.3.1.1 Organization/Membership*

Members of the LC Steering Committee will include, but not be limited to, NMFS, the Lower Columbia Fish Recovery Board, the Washington Governor's Salmon Recovery Office, the Washington Department of Fish and Wildlife, the Oregon Department of Fish and Wildlife, the Oregon Governor's Office, the Lower Columbia Estuary Partnership, and the Yakama Nation. Representatives of these entities constituted the steering committee during recovery plan development. As appropriate, these members may decide to include additional entities.

#### *11.3.1.2 Operations*

The LC Steering Committee will meet semi-annually or as needed. Policy issues will be resolved at the appropriate level, be it within the steering committee or within respective local, state, federal, and tribal authorities and agencies.

NMFS will serve as the convening partner and provide facilitation, venues, and other needs associated with convening meetings. Participating agencies and parties will fund their staff's involvement.

#### *11.3.1.3 Areas of Focus*

The LC Steering Committee will focus on four functional areas: (1) policy, (2) implementation, (3) research, monitoring, and evaluation, and (4) outreach. For these topic areas, the committee may establish work groups either as standing subcommittees or on an ad hoc basis. The decision to establish such subgroups will be determined based on the anticipated scope of work for each topic, LC Steering Committee members' available staffing and funding, and other considerations, as the LC Steering Committee considers appropriate. The intent of these efforts is to support coordinated and effective

implementation of this recovery plan. More detail on each functional area is provided below.

**Policy**

The LC Steering Committee will serve as a forum for coordinating and discussing policy issues at the subdomain level. The committee may elect to organize subgroups for specific issues. Focus areas could include identifying issues where joint advocacy would support implementation or effectiveness of Lower Columbia recovery actions; providing recovery-plan perspective and input on regulatory and management decisions that affect the Lower Columbia River ESUs and DPS; tracking the status of Lower Columbia-related activities in the NPCC, Federal Caucus, FCRPS litigation, Pacific Fisheries Management Council, and other regional forums; and, as appropriate, developing policy recommendations on specific issues. Subgroups on specific issues will be convened as appropriate.

**Implementation**

Implementation focus areas for the LC Steering Committee will include discussing the progress of implementation progress and coordinating and resolving issues related to implementation of actions that are regional in scope. Specific implementation-related activities could include tracking the status of implementation schedules for each management unit, helping to resolve issues related to Lower Columbia River harvest and hatchery actions, sharing significant accomplishments, promoting information and technology transfer, communicating priorities for future action, and identifying opportunities where shared advocacy and coordination would help implement key recovery actions. Subgroups may be convened and will consist of staff from management unit recovery planning entities and representatives from partners in funding programs and recovery efforts.

**Research, Monitoring, and Evaluation**

The LC Steering Committee will ensure that RME activities are appropriately coordinated throughout the subdomain. RME activities in which the committee engages could include ensuring that new information on VSP parameters is adequately reviewed and compiled and that population status summaries are updated accordingly, identifying high-priority knowledge gaps across ESUs and coordinating efforts to address them, identifying how to track threats criteria and providing annual summaries of applicable data, and seeking efficiencies across the subdomain. The LC Steering Committee will convene subgroups on these matters as needed and appropriate.

**Outreach**

Activities in this focus area will include developing and/or supporting outreach related to recovery of the Lower Columbia River ESUs and DP, such as drafting or reviewing NMFS' biennial reports to Congress and updates to key decision makers (elected officials, agency heads, etc). Subgroups consisting of representatives from state governors' staffs, co-manager policy leads, management unit representatives, and/or partner agency policy staff may be convened.

### 11.3.2 Management Unit Level

Each management unit planning lead has proposed an organizational structure for plan implementation at the management unit level. In Oregon and Washington, this structure is based on the structure used for development of the respective management unit recovery plans. These approaches differed somewhat and will continue to differ slightly. In Oregon, the Oregon Department of Fish and Wildlife led recovery plan development with assistance from the Oregon Governor's Natural Resources Office and the Lower Columbia River Recovery Planning Stakeholder Team. During implementation, an ODFW implementation coordinator will be the lead staff person for facilitating implementation of the recovery plan. In Washington, the Lower Columbia Fish Recovery Board developed the management unit plan and will coordinate implementation with guidance and support from the Washington Governor's Salmon Recovery Office. In the White Salmon management unit, NMFS, in coordination with the Washington Gorge Implementation Team (WAGIT), has taken the lead in coordinating implementation. NMFS encourages the formation of a Washington Gorge Area Regional Board to coordinate implementation in the White Salmon management unit, if local stakeholders determine that this is appropriate.[6]

For the purposes of implementation, the term "management unit leads" (MU leads) refers to the LCFRB, ODFW (through its Lower Columbia implementation coordinator, who will work in conjunction with Oregon's recovery implementation team) and, for the White Salmon, NMFS (through the Washington Gorge Implementation Team). The MU leads have three primary responsibilities with respect to implementation:

1. Developing implementation schedules. Each MU lead is responsible for developing an implementation schedule for that MU plan and updating the schedule as needed. Implementation schedules identify the following:

    - Recovery projects specific to plan actions for populations within the management units
    - Limiting factor(s) addressed by each project
    - Priority for completing the projects
    - Duration of and schedule for projects
    - Benefits of each project
    - Lead agency/entity to implement each population-specific project
    - Estimated cost for each project over a period of time

2. Coordinating implementation. Management unit leads are responsible for coordinating implementation of recovery actions identified in the management unit plan and implementation schedule. In this capacity, they serve to facilitate communication vertically (i.e., at different spatial scales related to recovery plan governance) and horizontally (i.e., among related programs and interests and outside of the recovery plan governance structure) within their respective inter-

[6] The Washington Gorge Area Regional Board could consist of representatives from Klickitat, Skamania, Yakima, and Benton counties, local landowners, the Yakama Nation, and possibly others. Such a board could also coordinate with the LCFRB.

and intra-agency organizational structures. Specific responsibilities include the following:

- Coordinating with federal and state agencies, tribes, local governments, and other stakeholders
- Developing implementation strategies for and facilitating implementation of actions that require coordination among various entities. Potential activities include local outreach; provision of incentives, technical assistance, and project funding; project management; and monitoring/reporting.

3. Tracking and reporting. Management unit leads are responsible for tracking and reporting on the progress of implementation of their plan actions. Specific responsibilities include:
    - Coordinating plan monitoring within the management unit and ensuring appropriate tracking and reporting of recovery actions
    - Coordinating plan research within the management unit, reporting results, and incorporating them into adaptive management.
    - Reporting on plan progress in relation to goals, strategies, and actions, using mechanisms and processes established for tracking progress, and highlighting plan successes and needs
    - Reviewing and revising the management unit plan implementation schedule as necessary, using monitoring and research to guide actions and incorporating adaptive management as needed
    - Representing the management unit in the LC Steering Committee and relevant subgroups as necessary

Performance of these responsibilities will be influenced by the capacity, authority, and priorities of the management unit leads. Full accomplishment will likely require other support structures or processes. Not all of these duties can be accomplished initially with the resources currently available. Prioritization of initial duties will be guided by the statutory requirements of the ESA and relevant state guidance.

#### *11.3.2.1 Oregon*

Oregon's recovery plan implementation framework is intended to provide a collaborative approach to implementation, along with scientific guidance, policy direction, information exchange and coordination, and linkage to state, ESU, and regional forums. Existing forums, groups, and partnerships will serve as the basis of Oregon's implementation framework, but additional resources and funding will be needed to make it work effectively and successfully. The basic components of Oregon's implementation structure include a recovery team, an implementation coordinator, an implementation team, a technical team, and stratum teams. The implementation framework will adapt and change as necessary to adjust to funding, available resources, and implementation needs (ODFW 2010). Oregon's implementation structure is illustrated in Figure 11-2 and described below.

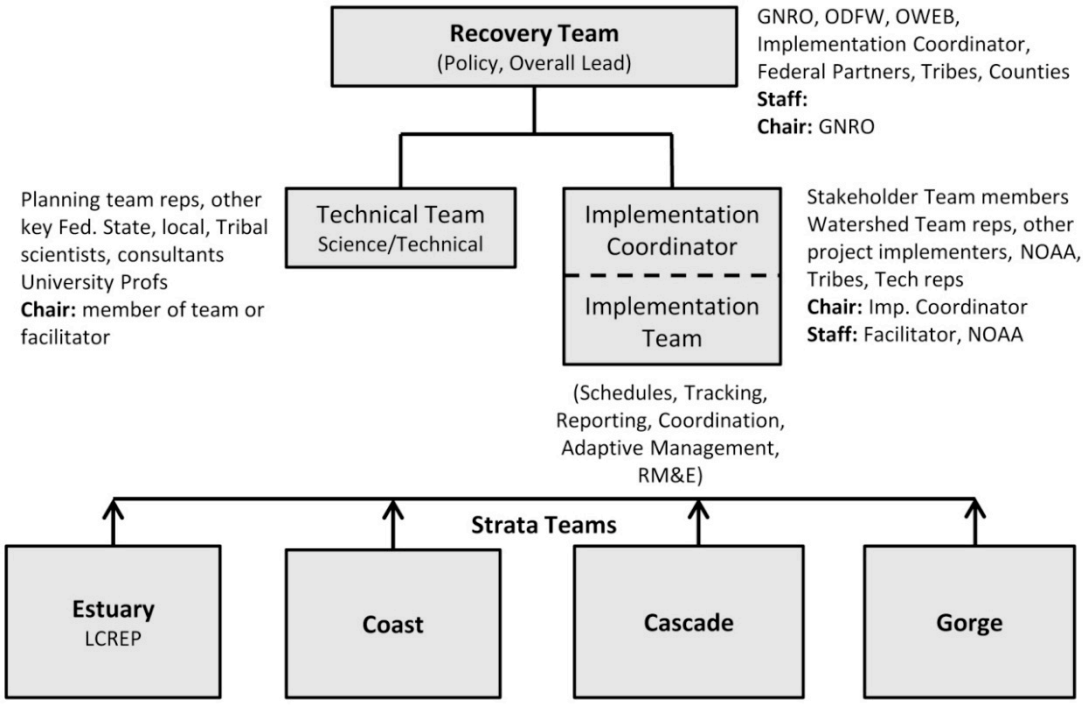


**Figure 11-2.** *Oregon's Organizational Implementation Structure*

**Recovery Team**

The recovery team provides oversight and vision for recovery plan implementation. This team is responsible for reporting to NMFS and shares accountability for species recovery in the Oregon management unit. The recovery team provides overall coordination and guidance to the technical and implementation teams, coordinates with other domain teams and the Oregon Plan core team, and serves as the state's representative to the LC Steering Committee. Members of the recovery team include the ODFW implementation coordinator and representatives from the Oregon Governor's Natural Resources Office, ODFW, the Oregon Watershed Enhancement Board, federal agencies, and local and tribal governments. Additional membership will include interested parties from counties, federal agencies, and non-governmental organizations. Although the recovery team serves a unique purpose and function, its members will also be on the implementation team (ODFW 2010).

**Implementation Coordinator**

An ODFW implementation coordinator will serve as Oregon's management unit lead for recovery plan implementation, acting under the advice and guidance of the recovery team. The implementation coordinator will work in conjunction with the implementation and stratum teams to plan, schedule, track, and report on action implementation, and—in coordination with technical teams—to develop, track, and report on RME activities. The implementation coordinator will also be a member of the recovery team. The implementation coordinator will lead the implementation team in its deliberations and actions, coordinate and lead development of 3-year implementation

schedules and adaptive management processes, coordinate and communicate with watershed teams (or individual implementation entities) and the Oregon Plan regional management teams (interagency regional manager forum), and coordinate implementation of actions for which ODFW is responsible. The coordinator will also ensure that ODFW staff engaged in regional forums for hydropower, harvest, and hatchery issues (including the FCRPS Biological Opinion, *U.S. v. Oregon*, Northwest Planning and Conservation Council, and Columbia Basin Fish and Wildlife Authority) understand the content and priorities of the recovery plan so they can advocate for and use it in those forums. Actions and decisions within these forums are important in successfully implementing the recovery plan and achieving recovery of Lower Columbia River salmon and steelhead (ODFW 2010).

**Implementation Team**

The implementation team provides advice, recommendations, and support to the implementation coordinator, who chairs the team. The team assists in communicating and coordinating with the stratum teams or local implementation groups; developing, tracking, and reporting on 3-year implementation plans; and tracking and reporting on research and monitoring. The implementation team also facilitates the collection and exchange of information, identifies and pursues funding sources, and provides for public participation, education, and outreach.

Implementation team members include members of the LCR Stakeholder Team (i.e., cities, utilities, private forest and agriculture representatives, conservation groups, federal representatives, watershed councils, and soil and water conservation districts), other local stakeholders, interest groups, and tribes and other governments. This diverse group represents differing perspectives, missions, and geographic areas, with the overall objective of collectively and synergistically working to achieve and advance recovery plan goals. NMFS will also participate on the implementation team (ODFW 2010).

**Technical Team**

The Oregon Technical Team will provide advice and guidance on technical and scientific issues related to RME, data analysis, and adaptive management that support and strengthen effective implementation of recovery plan actions. The technical team will be ad hoc and provide advice and guidance supplemental to that provided by the Oregon Plan Monitoring Team, which is an interagency monitoring forum. The technical team may include members of Oregon's recovery planning team and expert panel, as well as other key state, federal, tribal, utility, and private scientists and biologists, consultants, and university staff as appropriate for the particular issue needing their advice and guidance. A voluntary chair will facilitate team operations (ODFW 2010).

**Stratum Teams**

Stratum teams will be composed of the various local entities that implement local restoration and conservation actions via their respective authorities, mandates, missions, and work plans and will include watershed councils, soil and water conservation districts, federal and state agencies, local governments, tribes, conservation groups, and utilities. Stratum teams will be encouraged to form on a voluntary basis for a specific

stratum or may already exist. In many cases, watershed councils currently serve this function, with representation from a diversity of interest and action groups. Team chairs will be voluntary, and teams will be self-directed. Collaborative teams will facilitate coordination and prioritization of actions and the exchange of information within the stratum. They will provide project information to the implementation coordinator (or members of the implementation team) to support development of 3-year implementation schedules, plans, and reports. Collectively or individually, stratum teams will promote public involvement through outreach, education, and volunteer opportunities (ODFW 2010).

#### *11.3.2.2 Washington*

The Lower Columbia Fish Recovery Board will be the lead for implementation of the Washington management unit plan, which notes that achieving recovery will require the combined and coordinated actions of other federal and state agencies, tribal governments, and local governments, along with participation of nonprofit organizations, the business sector, and citizens. Collectively, these parties are referred to as implementing partners (LCFRB 2010a). The LCFRB organizational structure for implementation focuses on fulfilling three main functions: oversight, facilitation/coordination, and implementation. This structure is described below and illustrated in Figure 11-3.

**Oversight Authorities and Functions**

Key oversight bodies are entities with specific authority or responsibilities for managing the region's fish and wildlife resources. These include NMFS, the U.S. Fish and Wildlife Service, the state of Washington, the Cowlitz Tribe, the Yakama Nation, and the Northwest Power and Conservation Council.[7]

- NMFS has the primary federal authority for the Endangered Species Act, Sustainable Fisheries Act, and Mitchell Act as they apply to salmon and steelhead.
- The Washington Governor's Office has the authority to direct and coordinate state agency actions in support of recovery. The Washington Department of Fish and Wildlife has management authority for the state's fish and wildlife resources.
- The Yakama Nation is a co-manager of fish resources with the state and federal agencies.
- The Northwest Power and Conservation Council oversees implementation of the program to address the effects of the Federal Columbia River Power System on fish and wildlife.

[7] Because the scope of the Washington management unit plan is broader than just salmon and steelhead and includes bull trout, among other species for which the U.S. Fish and Wildlife Service has jurisdiction, that agency is included among the implementing and oversight entities for the Washington management unit plan.

Other federal, state, and local agencies have oversight responsibilities for water, natural resources, land management, and land use. These agencies are considered implementation partners because their responsibilities are not specific to fish management.

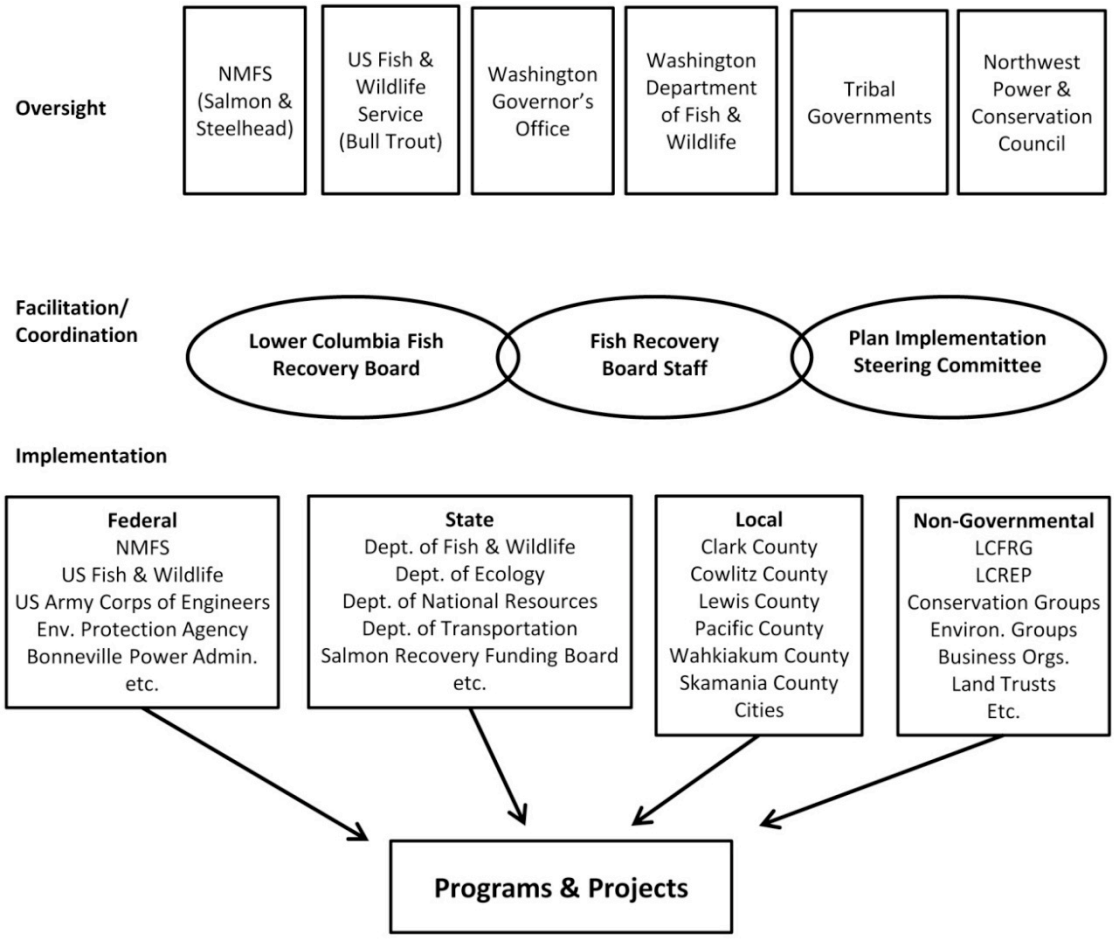


**Figure 11-3.** *Institutional Structure for Implementing Salmon Recovery in Washington Lower Columbia River Subbasins*

### Implementation Steering Committee and Functions

The Lower Columbia Fish Recovery Board, working with a plan implementation steering committee, will facilitate and coordinate efforts of the oversight bodies and implementing partners. NMFS and the U.S. Fish and Wildlife Service, Northwest Power and Conservation Council, Lower Columbia Estuary Partnership, Washington Department of Fish and Wildlife, Governor's Salmon Recovery Office, Washington Department of Ecology, U.S. Forest Service, counties, Cowlitz Indian Tribe, Yakama Nation, Chinook Tribe, and others will be invited to participate on the committee. The steering committee will assist the LCFRB in guiding implementation of the plan.

The steering committee will include representatives of the oversight bodies and a cross-section of implementing partners. Working groups consisting of steering committee

members and other implementing partners will be established as needed to address policy or technical issues or to coordinate implementation efforts.

Key functions of the LCFRB and steering committee are as follows:

- Develop and revise a 6-year regional implementation plan.
- Assist implementation partners in developing and implementing their individual 6-year implementation plans.
- Prepare and issue clarifications or interpretations of recovery plan provisions when needed.
- Prepare and issue revisions or updates to the Washington management unit plan.[8]
- Develop and implement the regional public education and outreach program.
- Conduct implementation and biological evaluations in accordance with the adaptive management provisions and benchmarks set forth in this plan.
- Track implementation of measures, actions, programs, and projects and issue annual progress reports.
- Facilitate and assist partners in resolving technical and policy issues that arise during implementation.
- Facilitate communications and the exchange of information and data among implementation and oversight partners.
- Coordinate the collection, management, synthesis, and evaluation of fish and habitat monitoring results collected by the partners.
- Develop implementation partnerships and agreements.

**Implementing Partners**

Recovery actions will be implemented through the programs and projects of numerous implementing parties, some of which are shown in Figure 11-3. The functions of the implementing partners are as follows:

- Develop and implement a 6-year plan for their recovery actions.
- Monitor and report on their implementation progress to the LCFRB/steering committee.
- Advise the LCFRB/steering committee of issues or developments that affect progress.

Each partner will set forth the tasks and schedule addressing assigned recovery actions and will document the partner's commitment to fulfilling its implementation

[8] NMFS would need to formally incorporate any substantial revisions to a management unit plan into this ESU-level recovery plan.

responsibilities in 6-year implementation work schedules (see Section 11.4, "Implementation Time Frames").

The actions identified for each partner are based on the partner's mission, capabilities, responsibilities, authority, and jurisdiction. Each partner is responsible for developing and fully implementing programs to address its assigned actions. Programs are expected to be technically sound and adequately funded and staffed. In the case of regulatory programs, agencies must be committed to taking enforcement actions when necessary to achieve the desired outcome.

In some instances an implementing partner may not have the full or exclusive authority to implement a recovery action. A case in point is the setting of harvest quotas pursuant to international treaty provisions. In such instances, implementing partners will share an implementation responsibility to cooperate in working to achieve the desired outcome.

If needed for coordination, the implementation steering committee may designate a lead agency in carrying out an implementation action shared by two or more partners. Even where a single implementing partner possesses the authority to fully implement a recovery action, the action is likely to be more effectively implemented with the involvement, agreement, and support of other partners.

To achieve this level of cooperation and coordination, implementing partners are requested to identify in their 6-year implementation work schedules interrelationships with other partners that will facilitate, affect, or complement implementation of their recovery actions.

#### *11.3.2.3 White Salmon*

NMFS, in conjunction with the Washington Gorge Implementation Team (WAGIT), is coordinating recovery plan implementation in the White Salmon subbasin. Implementation is being facilitated through the various existing programs, including harvest management programs, the Yakama Nation Fish Habitat Program, Washington's Lead Entity Process, watershed planning and implementation processes initiated under state regulations and coordinated through Klickitat County, various state and local habitat and watershed programs, and the various programs administered by the conservation districts. The WAGIT draws upon and works within the many existing programs rather than developing a parallel and potentially conflicting recovery implementation process.

### 11.3.3 NMFS' Role

NMFS' role in the recovery of Lower Columbia River ESUs is twofold. The first is to ensure that the agency's statutory responsibilities for recovery under the ESA are met. The second is to serve as the convening partner for the LC Steering Committee, provide leadership in coordinating among management units, provide NMFS' perspective regarding recovery plan implementation, and update steering committee members on issues relevant to recovery strategies.

#### *11.3.3.1 ESA Responsibilities*

NMFS is required to see that the agency's statutory responsibilities for recovery under the ESA are met. In this capacity, NMFS is responsible for the following:

- Ensuring that the recovery plan meets ESA statutory requirements, tribal trust and treaty obligations, and agency policy guidelines
- Developing ESU-wide performance measures consistent with the recovery strategies outlined in Chapters 6 through 9
- Conducting 5-year reviews
- Making delisting determinations
- Coordinating with other federal agencies to ensure compliance under the ESA
- Implementing recovery plans

#### *11.3.3.2 LC Steering Committee Convening Partner*

As the convener of the LC Steering Committee, the NMFS Northwest Regional Office, working through its Lower Columbia Recovery Coordinator and Domain Team, will do the following:

- Convene steering committee meetings on a regular basis (at least twice a year) and convene additional meetings as needed.
- Provide meeting facilitation services and manage the meeting process.
- Provide meeting venues.
- Prepare and distribute meeting notes and follow up on tasks agreed to by the steering committee.
- Serve as a central clearinghouse for information, to include ESU- or DPS-wide stock status, relevant federal scientific research, and gaps in recovery efforts for each ESU or DPS.
- As requested by the LC Steering Committee, establish and facilitate state, federal and tribal meetings necessary for the coordination of recovery activities.

### 11.3.4 Columbia River Estuary

The planning areas of the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) and the Oregon and Washington management unit plans overlap in the tidal reaches of the lower Columbia tributaries. The geographic overlap and the importance of improvements in intertidal rearing habitats for the recovery of some Lower Columbia River salmon and steelhead populations create a need in this subdomain for close coordination of estuary module implementation with implementation of the management unit plans.

Although not an officially designated management unit, the Columbia River estuary and plume, for implementation purposes, will be treated like a management unit. The Lower

Columbia Estuary Partnership and PC Trask and Associates, Inc., developed the estuary module under contract to NMFS.

Implementation of the 23 management actions in the module will require the efforts of a variety of federal, state, and local agencies, nonprofit organizations (such as watershed councils), private enterprises, and citizens. (Some potential implementers have been identified in Table 5-6 of the estuary module.) Although many of these entities have already been working to identify, prioritize, and implement salmon and steelhead recovery actions in the estuary and plume, effective implementation of all module actions will require additional coordination.

The first step in coordinated implementation of the module will be a conversation among all relevant entities and stakeholders to discuss near-term implementation priorities, with a goal of developing a 5-year implementation plan that provides specificity and certainty regarding near-term actions and that identifies lead entities for implementation of specific actions or projects. Given the complexities involved in implementing the full suite of module actions, this conversation also will be an opportunity to explore options for and recommend an organizational structure for coordinating and overseeing implementation of the estuary module. The Lower Columbia Estuary Partnership, a National Estuary Program established to bring about collaboration, would be an appropriate convener of this discussion.

## 11.4 Implementation Time Frames

The Oregon and Washington management unit plans are 25-year plans that schedule actions throughout that time frame. The estuary recovery plan also uses a 25-year time frame for implementing its 23 management actions. The White Salmon management unit plan uses a 10-year implementation time frame for planning purposes; however, the rate of change in the river now that PacifiCorp has removed Condit Dam may affect this timeline.

### 11.4.1 Oregon Management Unit Plan

In the Oregon management unit plan, many recovery actions are on 5-, 10-, 15-, 20-, and 25-year schedules. For priority actions, the plan requires 3-year implementation schedules with review and modifications, if needed, every 3 years. Members of the implementation team, watershed councils, and other implementing groups are encouraged to commit to the 3-year implementation schedule. Stratum teams, watershed councils, soil and water conservation districts, cities, counties, land managers and other implementers will use the action priorities outlined in the 3-year schedules to identify projects for implementation and to seek funding.

An implementation coordinator will develop a reporting process for gathering information from implementers, including government and funding entities, to develop annual reports on plan implementation that will be shared with implementers; funding entities; the implementation, recovery, and Oregon Plan teams; and the public. Annual reports will be used to assess the effectiveness of implementation at the population and ESU level. The implementation team will periodically (i.e., quarterly or annually) review progress toward implementation of priority actions and address local needs for more

effective implementation. A major revision of the Oregon plan is called for after 12 years.

### 11.4.2 Washington Management Unit Plan

The Washington management unit plan calls for new implementation schedules to be prepared at 6-year intervals. This cycle will coincide with the 6-year adaptive management checkpoints and allow the schedules to incorporate needed modifications. Six-year schedules may be revised every 2 years based on the adaptive management implementation evaluation checkpoint.

Entities or partners already carrying out recovery actions will be asked to prepare an implementation schedule for their actions. These individual implementation work schedules will be melded into a regional implementation schedule. The LCFRB, in consultation with its steering committee, will develop a detailed template for 6-year implementation work schedules and will assist and advise partners in developing their schedule. The 6-year implementation work schedules submitted by each partner will set out tasks and schedules for addressing assigned recovery actions and document the partner's commitment to fulfilling its implementation responsibilities.

### 11.4.3 White Salmon Management Unit Plan

In the White Salmon management unit, the Washington Gorge Implementation Team (WAGIT) has developed a detailed implementation plan. The WAGIT meets annually to update information on ongoing actions and make recommendations regarding next steps. The annual meeting includes discussion of information gained through research, monitoring, and evaluation that will help in identifying priority recovery projects, facilitating efficient implementation of the White Salmon management unit plan, or identifying needed modifications in the plan. The implementation plan will be updated annually to reflect changes in understanding of within-subbasin processes affecting salmonid production and of the extent to which recolonization is occurring. The plan also will be updated to reflect actions initiated or completed in the prior year. Klickitat County maintains a database that tracks projects in the White Salmon subbasin.

### 11.4.4 Columbia River Estuary Recovery Plan Module

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) includes a schedule for implementing the 23 management actions and each action's component projects. Schedule considerations are based primarily on the specific actions and the timing of component projects that depend on other projects. According to the estuary module, "developing a critical path for implementation of actions collectively is premature." A more comprehensive schedule will require knowing the level of effort and funding that will be committed to carrying out the management actions. The plan also notes the difficulties associated with establishing time frames when some of the actions in the 25-year plan may take decades to produce measurable effects.

### 11.4.5 NMFS Time Frames

NMFS is required to review the status of listed species every 5 years, prepare biennial reports to Congress, and update key decision makers, such as elected officials and agency heads.

# 12. Site-Specific Management Actions and Cost Estimates

ESA section 4(f)(1)(B) directs that recovery plans, to the maximum extent practicable, incorporate "a description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species" and "estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal."

Detailed information on management actions, schedules, and cost estimates are presented in the Washington, Oregon, and White Salmon management unit plans and the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (LCFRB 2010a, ODFW 2010, NMFS 2013, and NMFS 2011a; see Appendixes A through D). This chapter summarizes the information contained in those documents.

## 12.1 Site-Specific Management Actions

The management actions presented in the management unit plans are designed to address the limiting factors and threats to species and populations found in each management unit's respective geographic area of responsibility. Site-specific management actions are discussed in detail in the appended management unit plans. Site-specific actions with respect to the Columbia River estuary and plume, passage at Bonneville Dam, predation, and flow affecting conditions in the lower Columbia River, estuary, and plume are described in the 2008 FCRPS Biological Opinion (NMFS 2008f), its 2010 Supplement (NMFS 2010a), the recovery plan hydropower module (NMFS 2008a), and the estuary module (NFMS 2011a). The management actions presented in each management unit plan and the estuary module are summarized in the subsections below. In addition, Table 12-1 presents actions that are representative of the types of site-specific actions in the management unit plans (i.e., in Chapters 7, 8, and 9 of ODFW 2010, Chapters 5 and 10 of LCFRB 2010a, and Chapter 6 of NMFS 2013). The management unit leads will develop more detail on management actions during preparation of the implementation schedules described in Chapter 11 of this recovery plan.

**Table 12-1**
*Representative Recovery Actions*

| Threat Category | Representative Actions | Limiting Factors Addressed |
|---|---|---|
| Tributary Habitat | • Restore degraded off-channel habitats<br>• Streamline delivery of large wood to restoration sites<br>• Restore degraded riparian areas through planting or fencing | Channel structure and form: Bed channel and form |
| | • Restore riparian areas to improve water quality, provide long-term supply of large wood to streams, and reduce impacts that alter other natural processes | Channel structure and form: Instream structural complexity |
| | • Place gravel for spawning (below dams)<br>• Remove the Little Sandy River diversion (completed) | Sediment conditions and water quality[1]: Decreased sediment quantity (impaired sediment/sand routing and gravel recruitment) |
| | • Conduct sediment source analyses and reduce inputs<br>• Develop/implement stormwater management plans for urban areas and roads<br>• Identify and rectify problem legacy roads | Sediment conditions and water quality: Increased sediment quantity (turbidity from excessive fine sediment) |
| | • Protect intact riparian areas via easements and acquisition<br>• Explore cooperative water conservation measures<br>• Restore connectivity to small tributaries<br>• Restore degraded off-channel and riparian habitat<br>• Establish minimum ecosystem-based instream flows<br>• Identify and halt illegal water withdrawals | Water quantity: Altered hydrology<br>Water quantity: Decreased water quantity/downstream flows<br>Water quantity: Altered flow timing |
| Estuary habitat | • Protect intact riparian areas in the estuary and restore riparian areas that are degraded<br>• Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat<br>• Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats<br>• Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially<br>• Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary | Peripheral and transitional habitats: Estuary habitat quality (complexity and diversity)<br>Peripheral and transitional habitats: Reduced macrodetrital inputs |

[1] The data dictionary and limiting factors crosswalk consider turbidity as a subcategory of the water quality limiting factor and thus separately from sediment conditions, but the two limiting factors are presented together in this table because their mechanisms, causes, and effects in the lower Columbia River basin are so similar.

| Threat Category | Representative Actions | Limiting Factors Addressed |
|---|---|---|
| | • Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures | Peripheral and transitional habitats: Estuary habitat quality (complexity and diversity)<br>Peripheral and transitional habitats: Increased microdetrital inputs<br>Water quality: Temperature |
| | • Protect or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries<br>• Adjust the timing, magnitude, and frequency of flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume | Water quantity: Altered hydrology<br>Habitat quantity: Anthropogenic barriers |
| | • Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume | Sediment conditions: Decreased sediment quantity |
| | • Reduce the square footage of over-water structures in the estuary<br>• Reduce the effects of vessel wake stranding in the estuary | Peripheral and transitional habitats: Estuary habitat quality (complexity and diversity) |
| | • Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary<br>• Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants<br>• Restore or mitigate contaminated sites<br>• Implement stormwater best management practices in cities and towns | Toxic contaminants in water and biota<br>Water quality: Temperature |
| Hydropower | • Remove the Little Sandy water diversion (completed), Powerdale Dam on the Hood River (completed), and Condit Dam on the White Salmon River (completed)<br>• Implement measures in the 2008 FRCRPS BiOp and its 2010 Supplement to improve adult and juvenile passage at Bonneville Dam<br>• Maintain screens and fish passage structures<br>• Reintroduce coho and spring Chinook salmon and winter steelhead upstream of tributary dams in the upper Cowlitz and North Fork Lewis subbasins (per FERC relicensing agreements)<br>• Develop, maintain, and operate effective juvenile and adult passage facilities in the Cowlitz and Lewis subbasins | Habitat quantity: Access (anthropogenic barrier) |

| Threat Category | Representative Actions | Limiting Factors Addressed |
|---|---|---|
| | • Operate the hydro system in the North Fork Lewis and Cowlitz subbasins to provide appropriate flows for spawning and rearing habitat in areas downstream of the hydro system (i.e., maintain a flow regime that includes minimum flow requirements)<br>• Maintain adequate water flows in Bonneville Dam tailrace and downstream habitats throughout salmon migration, incubation, and rearing periods | Water quantity: Altered hydrology |
| | • Implement PGE's FERC agreement for the Clackamas River Hydroelectric Project (includes downstream passage measures, placement of spawning gravel below River Mill Dam, and habitat mitigation and enhancement) | Habitat quantity: Access (anthropogenic barrier)<br>Sediment conditions: Decreased sediment quantity<br>Channel structure and form: Bed and channel form<br>Channel structure and form: Instream structural complexity |
| | • Restore or create off-channel habitat or access to off-channel habitat (includes revegetation) | Water quantity: Altered hydrology<br>Peripheral and transitional habitats: Side channel and wetland conditions<br>Peripheral and transitional habitats: Floodplain condition<br>Peripheral and transitional habitats: Estuary conditions<br>Riparian condition, including large wood recruitment<br>Water quality: Water temperature<br>Toxic contaminants |
| | • Restore instream habitat complexity, including large wood placement | Channel structure and form: Bed and channel form<br>Channel structure and form: Instream structural complexity |
| Hatcheries | • Maintain existing wild fish sanctuaries and limit hatchery-origin spawners to levels consistent with the target status of each population<br>• Coded-wire tag enough fish from each hatchery to allow identification of the hatchery program of origin<br>• Mark all hatchery-origin steelhead and coho and Chinook salmon (to facilitate mark-selective fishing)<br>• Change acclimation or release strategies to reduce straying<br>• Reduce or eliminate some hatchery releases<br>• Shift some hatchery production to programs further downstream<br>• Make use of conservation hatchery programs for reintroduction or supplementation; identify appropriate time period, stock, timing, and strategies<br>• Integrate wild broodstock into hatchery programs<br>• Provide or improve fish passage at hatcheries (and at road, railroad and I-84 crossings) | Population diversity: Impaired productivity and diversity |

| Threat Category | Representative Actions | Limiting Factors Addressed |
|---|---|---|
| Harvest | • Broaden the use of mark-selective fishing methods (e.g., develop new gear and methods for commercial fishing)<br>• Refine the coho harvest matrix to ensure that it adequately accounts for weaker components of the ESU<br>• Develop an abundance-based harvest approach for fall Chinook<br>• Continue to review harvest rates and base future rates on observed indicators in populations<br>• Manage Columbia River fisheries by time, area, and gear to target hatchery fish<br>• Fill information gaps regarding hatchery-origin spawner escapement, natural productivity, and harvest impact rates | Direct mortality: Harvest |
| Ecological Interactions | • Redistribute nesting tern colonies in the Columbia River estuary<br>• Reduce double-crested cormorant habitat in the Columbia River estuary and encourage dispersal to other locations<br>• Reduce pinniped predation on salmon and steelhead<br>• Manage pikeminnow and other piscivorous fish to reduce predation on salmonids (e.g., modify habitat, increase pikeminnow bounty program)<br>• Evaluate ecological interactions between hatchery-origin and natural-origin salmon and steelhead in the Columbia River estuary | Direct mortality: Predation |
| | • Implement regulatory, control, and education measures to control introduced, invasive, or exotic species and prevent new invasions | Direct mortality: Predation, pathogens<br>Food: Competition<br>Food: Altered prey composition and diversity |

### 12.1.1 Washington Management Unit Plan

The Washington management unit plan identifies 117 strategies (see Chapter 5, "Strategies and Measures," of LCFRB 2010a) and 365 actions (see the table in Chapter 10, "Implementation," Section 10.9, of LCFRB 2010a) that address threats in the following general categories:

- Tributary habitat
- Estuary/mainstem habitat
- Hydropower
- Harvest
- Hatcheries
- Ecological interactions (including predation)
- Climate and ocean conditions

These include the 23 actions called for in the *Columbia River Estuary ESA Recovery Plan Module* (NMFS 2011a). All actions are expected to be completed within 25 years, although the effects of the actions may not be realized for some time thereafter.

Management actions in the Lower Columbia Fish Recovery Board's geographic area of responsibility are discussed further in Chapters 5 and 10 ("Strategies and Measures" and "Implementation") of LCFRB (2010a).

### 12.1.2 Oregon Management Unit Plan

Like the Washington management unit plan, the Oregon management unit plan (ODFW 2010) orients its actions around threat categories. Actions are identified in the management unit plan—and costs estimated—for the following general categories of threats:

- Tributary habitat, including habitat protection and restoration
- Harvest
- Hatchery effects
- Predation

The Oregon management unit plan identifies 14 strategies and 308 management actions (see Tables 7-1, 7-3, and 9-3 in ODFW 2010). Of the 308 actions, 23 are actions called for in the estuary module (NMFS 2011a), and 18 are reasonable and prudent alternative actions brought forward from the 2008 FCRPS Biological Opinion (NMFS 2008f). All actions are expected to be completed within 25 years, although the effects of the actions may not be realized for some time thereafter.

Management actions in Oregon are discussed further in Chapters 7, 8, and 9 ("Strategies and Actions" "Research, Monitoring, and Evaluation," and "Implementation") of ODFW (2010).

### 12.1.3 White Salmon Management Unit Plan

The strategy for recovery actions in the White Salmon River consists of seven fundamental components:

- Assessment of pre-dam removal fish populations and habitat conditions
- Removal of Condit Dam
- Reintroduction of fish into the reaches formerly blocked by Condit Dam
- Assessment of actions needed for recovery once the dam is removed
- Habitat restoration of the reaches located under the current reservoir (Northwestern Lake) and below Condit Dam
- Habitat restoration in the reaches above Northwestern Lake to support reintroduced fish
- Assessments and monitoring of conditions to determine whether implemented actions are working and sufficient

The removal of Condit Dam is central and essential to the White Salmon recovery strategy. The decision to decommission the dam was made by the dam's owner (PacifiCorp) after comparing the benefits of continued operation with the cost to install fish ladders as proposed during relicensing negotiations with the Federal Energy Regulatory Commission. The dam's removal is considered a baseline action because it is not an action called for under the recovery plan and would occur regardless. Its removal presents an opportunity to reintroduce salmon into historical habitat blocked by the dam's original construction. The White Salmon plan's strategy and recovery management actions cannot succeed without the dam being removed.

The White Salmon management unit plan (NMFS 2013) identifies 14 strategies (see Table 6-1 of NMFS 2013) and 52 management actions (see Table 7-2 of NMFS 2013). Assessments will further inform actions needed for recovery. The majority of actions will be implemented within 5 years of removal of Condit Dam, which took place in September 2012. Additional actions may be identified after that time period, depending on the results of monitoring and evaluation activities. Recovery of the species in the White Salmon subbasin is expected to occur over decades. Natural recolonization is the preferred reintroduction option for spring Chinook, coho, and chum, while reintroduction using hatchery-origin adults is the preferred option for fall Chinook.

Management actions for the White Salmon subbasin are discussed further in Chapters 6 and 7 ("Recovery Actions and Strategies" and "Implementation and Cost Estimates") of the White Salmon management unit plan (NMFS 2013).

### 12.1.4 Estuary Module

The *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) presents 23 management actions or strategies, each supported by two to five programmatic "conceptual-level projects" (see Table 5-1 of NMFS 2011a). All actions are expected to be completed within 25 years, although the effects of the actions may not be realized for some time thereafter. Many of these actions and strategies call for a methodical approach of data collection, study, and careful design before projects are implemented on the ground so as to provide the maximum assurance that the actions implemented will be biologically effective. Consequently, the scope and nature of a project could change as better information is collected.

Because the actions in the estuary module have basinwide scope and are expected to benefit all 13 listed ESUs and DPSs in the Columbia Basin, the estuary module is incorporated by reference into all Columbia Basin salmon and steelhead recovery plans. For more information on management actions in the Columbia River estuary and plume, see Chapter 5 of the estuary module (NMFS 2011a).

## 12.2 Cost Estimates

This section provides 5-year and total cost estimates as called for under ESA and NOAA Interim Recovery Planning Guidance, version 1.3, dated June 2010.

Cost estimates for recovery projects were provided by the management unit planners where information was sufficient to allow reasonable estimates to be made. In some cases this was done in coordination with a NMFS economist at the Northwest Fisheries Science Center in Seattle and with input and review from in-house and/or regional experts.

Recovery planners developed cost estimates for recovery actions using the methods described in each management unit plan and summarized below. Although some management unit plans display the cost of baseline actions because they are necessary for recovery,[2] the costs of baseline actions are not included in the cost estimates.

Administrative costs are treated differently in each management unit plan. The administrative costs for actions identified in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) are embedded in the action cost estimate. The Washington management unit plan addresses administrative coordination, direction, and tracking as line-item costs. The Oregon and White Salmon management unit plans use mixed approaches, with some administrative costs specifically identified while others are embedded in action cost estimates.

Research, monitoring, and evaluation costs also vary among the management unit plans. In many cases, RME costs have yet to be determined. Those that can be estimated at this

[2] "Baseline actions" are those programs that are already in existence or that would occur regardless of recovery plans.

point are included in the management unit plans and incorporated into the estimates shown below.

All yearly costs identified in the management unit plans are presented in present-year dollars (that is, without adjusting for inflation). The total costs are the sum of the yearly costs without applying a discount rate.

The total estimated cost of recovery actions for the four threatened species found in the lower Columbia River over the next 25 years is about $2.1 billion, of which about $614 million is anticipated to be needed in the first 5 years (see Table 12-2). These estimates include expenditures by local, tribal, state, and federal governments, private business, and individuals in implementing capital projects and non-capital work, as well as administrative costs for supervision and coordination. The total costs in Table 12-2 include $592 million ($164 in the first 5 years) for implementation of actions in the estuary module (NMFS 2011a); these actions have basinwide scope and are expected to benefit all 13 listed ESUs and DPSs in the Columbia Basin but are included in Table 12-2 because of their shared geography with the Lower Columbia River ESUs. Not included in Table 12-2 are expenses associated with implementing the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a).

Note that all estimates in Table 12-2 and the subsequent discussion are rounded to the nearest million.

**Table 12-2**
*Summary of Cost Estimates*

| Management Unit | 5-Year Cost Estimate (millions) | 25-Year Cost Estimate (millions) |
|---|---|---|
| Washington (LCFRB 2010a)[3] | $245 | $738 |
| Oregon (ODFW 2010)[4,5] | $189 | $758 |
| White Salmon (NMFS 2013)[6] | $16 | $16 |
| Estuary Module (NMFS 2011a)[7] | $164 | $592 |
| TOTAL | $614 | $2,104 |

These estimates are based on the best available information at the time the management unit plans were completed and are expected to change as implementation plans are developed and actions are more clearly scoped and planned. It is therefore likely that estimated costs will increase substantially given the significant number of actions for which no costs could be estimated at the time of plan completion.

The cost estimates in each management unit plan are summarized below.

### 12.2.1 Washington Management Unit Plan

The Washington management unit plan (LCFRB 2010a) provides estimated costs for actions undertaken solely to address salmon recovery. The plan does not estimate baseline costs, i.e., costs for actions that may be critical to recovery efforts but are mandated by laws, regulations, or policy directives other than Endangered Species Act recovery plans and would thus occur irrespective of recovery planning efforts.

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[3] The Washington management unit plan estimated costs for a short-term (10-year) and long-term (25-year) period. The 5-year estimate shown in Table 12-2 is extrapolated by dividing the 10-year estimate in half. NMFS worked with Washington recovery planners to add a 2 percent operations and maintenance cost factor to capital projects, beginning with the estimated project completion date. This addition made the Washington management unit plan consistent with the other management unit plans.
[4] The 5-year estimate was extrapolated from Table 9-3 of ODFW (2010). The estimate for the 25-year period includes a 2 percent maintenance cost factor added to capital projects, beginning with the estimated project completion date.
[5] Table 9-3 of ODFW (2010) indicates a number of actions scheduled to begin within the next 5, 10, 15, or 25 years. For the purposes of this table, unless otherwise specified, all are assumed to begin the first year the plan is put into effect.
[6] Most actions in the White Salmon management unit plan will occur within 5 years of removal of Condit Dam, which took place in September 2012. This table assumes that all actions, including the dam's removal, will occur within the first 5 years of plan implementation. Additional actions may be added pending the results of RME and assessment efforts.
[7] The 5-year estimate is extrapolated from Tables 5-6 and 6-7 of the estuary module (NMFS 2011a).

Dam operational improvements and predation management actions are addressed in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a), NMFS hydropower module, and FERC licensing agreements and are considered baseline costs. Estuary costs are quoted from the estuary module cost estimates for informational purposes only; they are not included in the management unit plan totals indicated below or in the Washington management unit costs in Table 12-2.

Research and monitoring needs are expected to be met largely through a combination of new and ongoing efforts by federal and state agencies, local governments, and research organizations, the outlays for which are considered baseline costs. Additional research and monitoring are anticipated to fill information gaps not addressed by existing programs. The costs for this additional effort will be estimated once more complete information is available. (LCFRB 2010a, Volume I, Section 11.7)

The costs for stream habitat restoration are estimated on a cost-per-mile basis developed from habitat project assessments conducted for selected subbasins in the region (the Lower Cowlitz River [Lower Columbia Fish Recovery Board 2007], Lower East Fork Lewis River [Lower Columbia Fish Recovery Board 2009b], Abernathy and Germany Creeks [Lower Columbia Fish Recovery Board 2009a], and Grays River [Lower Columbia Fish Recovery Board 2009c]). For each subbasin, habitat improvement targets identified for each species were used to estimate miles of stream treatment consistent with recovery. Estimates included initial project implementation and long-term maintenance costs. Costs for fishery- and hatchery-related recovery costs were estimated for those actions outside of baseline fishery and hatchery management programs from data provided by the Washington Department of Fish and Wildlife and its draft Conservation and Sustainable Fishery Plan. Estimates for implementation coordination and administration are provided.

The Washington management unit plan envisions a 25-year implementation period and provides cost estimates for the near term (the first 10 years) and long term (years 11 through 25). The total estimated cost for the 25-year implementation period for recovery-related habitat, fishery, and hatchery actions and associated coordination and administration is $703 million (LCFRB 2010a, Volume I, Section 11.8). For this roll-up plan, NMFS added post-construction maintenance costs, estimated at 2 percent per year for 15 years, to the costs for habitat restoration, for a total of $738 million.[8] The estimated cost for the 2010-2014 period is $245 million.

Cost estimates are discussed further in Chapter 11, "Costs," of LCFRB (2010a).

### 12.2.2 Oregon Management Unit Plan

The Oregon management unit plan envisions a 25-year time frame for recovery and conservation action implementation, with a formal assessment planned at the 12-year point. Action implementation is presented as occurring currently (i.e., "ongoing"); immediately after plan adoption; in 5-, 10-, 15-, and 25-year time frames; or in a specific

[8] These maintenance costs were added to achieve consistency among management unit plans and were developed in coordination with Washington recovery planners.

year (such as 2010). Cost estimates are provided for new actions or current program expansions that are called for in the recovery plan, unless there is not enough information for an estimate. Actions required under other statutes or programs are considered baseline costs and not included, although their successful implementation is considered necessary for the overall recovery effort.

Actions called for in the 2008 FCRPS Biological Opinion and its 2010 Supplement (NMFS 2008f and 2010a) are included in the management unit plan for informational purposes but not included in the management plan costs, which are indicated in Table 12-2 above or in Table 9-3 of ODFW (2010). Actions from the estuary module (NMFS 2011a) are presented in the Oregon management unit plan, but their costs are not included in the management unit plan totals below or in the Oregon management unit costs in Table 12-2..

The cost estimating methodologies for tributary habitat actions consisted of either (a) calculation of the quantity of actions necessary and determination of unit costs, (b) expert opinion, or (c) applicable estimates from other plans. Costs for harvest, hatchery, and predation actions were based on the expert opinion and professional judgment of the Oregon Department of Fish and Wildlife. The cost estimate includes a 2 percent maintenance cost for capital projects for 20 years.

The total cost for the 25-year implementation period, not including baseline estuary or hydropower actions, is estimated to be $758 million. The estimated cost for the first 5 years is $189 million.

For further discussion of Oregon management unit plan cost estimates, see Chapter 9 ("Implementation") of ODFW (2010), including, Section 9.1 ("Action Details: Locations, Schedule, Costs, and Potential Implementers") and Table 9-3.

### 12.2.3 White Salmon Management Unit Plan

The decommissioning and removal of Condit Dam is central to the White Salmon recovery strategy. The costs of dam removal are being born by the PacifiCorp power company.

Removal of Condit Dam and associated reintroduction and habitat improvement actions are estimated to cost between $12 and $15 million. Additional habitat restoration and harvest and hatchery management actions are estimated to cost about $14 million.

Numerous RME actions are identified in the White Salmon management unit plan. The results of studies will help with prioritization of actions within the subbasin. It is estimated that the RME actions will cost roughly $2 million over a 5-year period.

Because dam removal is considered a baseline action, Table 12-2 includes only the additional habitat restoration and harvest and hatchery management action and RME cost estimates. The total estimated cost for the first 5-year period for restoring

anadromous populations in the White Salmon River, not counting the baseline action of Condit Dam removal, is estimated to be about $16 million.[9]

Additional costs for recovery are likely to be incurred beyond the initial 5-year period. These costs cannot be estimated until the RME has been completed.

For further discussion of cost estimates for the White Salmon subbasin, see Chapter 7 of NMFS (2013), specifically Section 7.2 ("Costs") and Tables 7-1 and 7-2.

### 12.2.4 Estuary Module

Cost estimates in the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) address direct, incremental costs of actions over and above baseline activities. Most of the estimates provided were developed by the consulting firm PC Trask & Associates, Inc., and members of the Lower Columbia Estuary Partnership, based on action implementation experience and historical records. Other estimates were provided by federal agency experts, most notably NMFS and the U.S. Army Corps of Engineers.

Total costs for actions in the estuary module are estimated at $528 million over the module's 25-year planning horizon. This estimate includes the costs of actions that are currently being implemented or that have already been completed, with implementation having begun in 2006. The cost estimate for the 5-year period 2010 to 2014, extrapolated from Table 5-6 of the estuary module, is $149 million.

Some of the module actions identified above include RME projects and associated cost estimates that are included in the estuary action cost estimates identified above. Table 6-6 of the estuary module identifies additional monitoring needs not directly associated with other actions. The estimated cost of these additional RME actions is $64 million over the module's 25-year planning horizon. The portion of this cost occurring over the period 2010 to 2014, as extrapolated from Table 6-7 of the estuary module, is about $15 million.

The total estimate for estuary actions and RME is $592 over the module's 25-year planning horizon, with $164 million estimated for the period 2010 to 2014. Although costs of implementing estuary module actions are included in this recovery plan for Lower Columbia River ESUs, the actions in the estuary module are expected to benefit all 13 listed ESUs and DPSs in the Columbia Basin and the estuary module is incorporated by reference into all Columbia Basin salmon and steelhead recovery plans.

For further discussion of the estuary module's cost estimates, see Table 5-6 of the module (NMFS 2011a).

[9] Totals do not sum because of rounding.

## 12.3 Time Estimate

There are unique characteristics and challenges in estimating the time required for salmon and steelhead recovery given the complex relationship of these fish to their environment and to human activities in the water and on land. Examples of the uncertainties that preclude a more precise estimate of time include biological and ecosystem responses to recovery actions and the unknown impacts of future economic, demographic, and social developments.

Consequently, the management unit plans provide a 25-year period for action implementation. The management unit authors believe, and NMFS concurs, that it may take longer than 25 years for the biological effects of management actions to be fully realized and for recovery of Lower Columbia River salmonid species to occur. Rather than speculate on conditions that may or may not exist that far into the future, this recovery plan relies on ongoing monitoring and periodic plan review regimes to add, eliminate, or modify actions through adaptive management as information becomes available and until such time as the protection of the Endangered Species Act is no longer required.

NMFS believes it most appropriate to focus on the first 5 years of implementation and in 5-year intervals thereafter, with the understanding that before the end of each 5-year implementation period, specific actions and costs will be estimated for subsequent years.

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# ESA Recovery Plan for the White Salmon River Watershed

**June 2013**

**Prepared by**
**National Marine Fisheries Service**
**Northwest Region**

## DISCLAIMER

Endangered Species Act (ESA) recovery plans delineate reasonable actions which the best available information indicates are necessary for the conservation and survival of listed species. Plans are published by the National Marine Fisheries Service (NMFS), usually with the assistance of recovery teams, state agencies, local governments, salmon recovery boards, non-governmental organizations, interested citizens of the affected area, contractors, and others. ESA recovery plans do not necessarily represent the views, official positions, or approval of any individuals or agencies involved in the Plan formulation, other than the NMFS. They represent the official position of NMFS only after they have been signed by the Northwest Regional Administrator. ESA recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new information, changes in species status, and the completion of recovery actions.

The White Salmon River Watershed Recovery Plan straddles two NMFS Recovery Domains: the lower Columbia/Willamette River Recovery Domain, and the middle Columbia River (MCR) Steelhead Recovery sub-domain of the Interior Columbia River Recovery Domain. As such, the White Salmon River Watershed Recovery Plan is appended to both the lower Columbia/Willamette River and the MCR Steelhead Recovery Plans.

With respect to both the lower Columbia/Willamette River Recovery Plan and the MCR Steelhead Recovery Plan to which the White Salmon Watershed Recovery Plan is appended, where areas of disagreement arose between a management unit plan and a species level, evolutionarily significant unit or distinct population segment plans, NMFS worked with the relevant parties to resolve the differences, and, in a few cases, identified in the evolutionarily significant unit/distinct population segment plans, decided not to incorporate the disputed material in the evolutionarily significant unit or distinct population segment plans. NMFS reserves the right to decide whether or not to incorporate any such disputed materials into the species level plans.

ESA recovery plans provide important context for NMFS determinations pursuant to section 7(a)(2) of the ESA. However, recovery plans do not place any additional legal burden on NMFS or the action agency when determining whether an action would jeopardize the continued existence of a listed species or adversely modify critical habitat. The procedures for the section 7 consultation process are described in 50 CFR 402 and are applicable regardless of whether or not the actions are described in a recovery plan.

# Contents

**Acronyms and Abbreviations** ..... **vii**
**Recovery Planning Glossary** ..... **ix**
**Executive Summary** ..... **xv**
**1 Introduction** ..... **1-1**
1.1 Purpose of Plan ..... 1-2
1.1.1 ESA Requirements ..... 1-3
1.1.2 Coordination with Others ..... 1-3
1.2 Context of Plan Development ..... 1-5
1.2.1 Planning Forum ..... 1-7
1.3 How NMFS Intends to Use the Plan ..... 1-7
**2 Biological Background** ..... **2-1**
2.1 Populations and Major Population Groups ..... 2-1
2.2 Physical Setting ..... 2-8
2.3 Ecosystem Conditions ..... 2-8
2.3.1 Hydrology ..... 2-9
2.3.2 Migration Barriers ..... 2-10
2.3.3 Riparian Function and Conditions ..... 2-10
2.4 Life History Characteristics ..... 2-11
2.4.1 White Salmon River Chinook salmon ..... 2-11
2.4.2 White Salmon River coho salmon ..... 2-17
2.4.3 Upper Gorge chum salmon ..... 2-19
2.4.4 White Salmon River steelhead ..... 2-21
2.5 Hatchery Production and Releases ..... 2-25
2.6 Harvest ..... 2-27
**3 Recovery Goals and Viability Criteria** ..... **3-1**
3.1 Recovery Goals ..... 3-1
3.2 Biological Viability Criteria ..... 3-2
3.2.1 ESU/DPS Viability Criteria ..... 3-2
3.2.2 DPS and MPG Viability Criteria ..... 3-10
3.3 Threats Criteria ..... 3-12
**4 Current Status Assessment** ..... **4-1**
4.1 Risk of Extinction: Willamette/Lower Columbia TRT ..... 4-1
4.2 Extinction Risk: Interior Columbia TRT ..... 4-3
**5 Limiting Factors and Threats** ..... **5-1**
5.1 Blocked Migration and Impaired Passage ..... 5-2
5.2 Freshwater Habitat ..... 5-3
5.2.1 Lower White Salmon River Habitat Below Condit Dam ..... 5-3
5.2.2 Habitat Upstream of Condit Dam ..... 5-4
5.3 Hatchery Production and Releases ..... 5-6
5.4 Harvest ..... 5-7
5.5 Federal Columbia River Hydrosystem ..... 5-12
5.5.1 Hydro Project Impacts on Outmigrating Smolts ..... 5-13
5.5.2 Hydro Project Impacts on Migrating Adults ..... 5-13
5.6 Predation, Competition and Disease ..... 5-13
5.7 Ocean Conditions ..... 5-14

5.8 Climate Change ..... 5-14
5.9 Other Large-Scale Threats ..... 5-15
**6 Recovery Strategy and Actions ..... 6-1**
6.1 Salmon and Steelhead Reintroduction Plans ..... 6-1
6.1.1 Fall Chinook salmon ..... 6-2
6.1.2 Spring Chinook salmon ..... 6-3
6.1.3 Coho salmon ..... 6-4
6.1.4 Chum salmon ..... 6-4
6.1.5 Steelhead ..... 6-5
6.1.6 Monitoring and Evaluation ..... 6-6
6.2 Freshwater Habitat Strategies and Actions ..... 6-9
6.2.1 High Priority Reaches for Habitat Protection/Restoration and Proposed Actions ..... 6-16
6.3 Hatcheries ..... 6-19
6.4 Harvest-Related Strategies and Actions ..... 6-19
6.5 Hydro-Related Strategies and Actions ..... 6-20
**7 Implementation and Cost Estimates ..... 7-1**
7.1 Implementation ..... 7-1
7.2 Costs ..... 7-2
**8 Monitoring, Research, and Evaluation for Adaptive Management ..... 8-3**
8.1 Designing a Monitoring and Evaluation Program to Support Adaptive Management ..... 8-3
8.2 Adaptive Management ..... 8-4
8.3 Critical Uncertainties ..... 8-4
8.3.1 Research ..... 8-4
8.3.2 In-Watershed Research Needs ..... 8-5
8.3.3 Out-of-Watershed Research Needs ..... 8-5
8.4 Monitoring ..... 8-6
8.4.1 Implementation Monitoring ..... 8-7
8.4.2 Status/Trend Monitoring ..... 8-7
8.4.3 Effectiveness Monitoring ..... 8-8
8.5 Consistency with Other Monitoring Programs ..... 8-8
8.6 Coordination ..... 8-9
8.7 Evaluation Schedule ..... 8-9
8.8 Monitoring and Evaluation Plan ..... 8-10
**9 References ..... 9-1**
**Appendix I. Options for Salmon and Steelhead Reintroduction ..... 1**
**Appendix II. Current Efforts and Regulations Addressing and Protecting Population Productivity in the White Salmon Watershed ..... 1**
**Appendix III. Jewett Creek ..... 1**
**Appendix IV. White Salmon River Implementation Schedule: Summary of Actions and Potential Costs to Restore White Salmon River Anadromous Fish Populations and Their Habitat ..... 1**

# List of Figures

Figure ES-1. White Salmon watershed in Washington State (NPCC 2004) ..... xviii

Figure 1-1. White Salmon watershed in Washington State ..... 1-2

Figure 2-1. Historical fall and late fall demographically independent populations in the Lower Columbia River Chinook salmon ESU (Myers et al. 2006) ..... 2-2

Figure 2-2. Historical spring demographically independent populations in the lower Columbia River Chinook salmon ESU (Myers et al. 2006) ..... 2-3

Figure 2-3. Historical demographically independent populations in the lower Columbia River Coho salmon ESU (Myers et al. 2006) ..... 2-4

Figure 2-4. Historical demographically independent populations in the Columbia River chum salmon ESU (Meyers et al. 2006) ..... 2-5

Figure 2-5. Historical summer and winter steelhead populations in the middle Columbia River DPS (ICTRT 2004; ICTRT 2007b). Note populations in gray are extirpated or functionally extirpated ..... 2-7

Figure 2-6. White Salmon River watershed topography and hydrology (NPCC 2004) ..... 2-9

Figure 2-7. Wild and total tule fall Chinook salmon escapement for the White Salmon River from 1992-2003 (USFWS 2004) ..... 2-12

Figure 2-8. Possible extent of historic spawning distribution of Chinook salmon in the White Salmon River (NPCC 2004) ..... 2-14

Figure 2-9. Potential extent of historical spawning distribution of coho salmon in the White Salmon River (McElhany et al. 2004) ..... 2-18

Figure 2-10. Major Population Groups (MPGs) and populations of middle Columbia steelhead. Note the White Salmon steelhead population is considered functionally extirpated (ICTRT 2007b)2-22

Figure 3-1. Hierarchical levels of salmonid population structure as defined by the TRTs for ESU/DPS recovery planning ..... 3-3

Figure 3-2. Example of an abundance/productivity viability curve (ICTRT 2007a) ..... 3-10

Figure 4-1. Intrinsic habitat potential and Major Spawning Area for the White Salmon River summer/winter steelhead (ICTRT 2008) ..... 4-5

Figure 8-1. NMFS Listing Status Decision Framework ..... 8-3

# List of Tables

Table ES-1. ESA listed DPS/ESU in the White Salmon River .....xvi

Table ES-2. Recovery Strategies and Actions for White Salmon River Salmon and Steelhead Populations .....xxix

Table 2-1. Key habitat by life stage and time period for fall/spring Chinook salmon (NPCC 2004) ... 2-15

Table 2-2. Key habitat by life stage and time period for White Salmon River coho salmon ..... 2-19

Table 2-3. Key habitat by life stage and time period for steelhead (NPCC 2004) ..... 2-24

Table 3-1. Population viability criteria (McElhany et al. 2003; McElhany et al. 2006)..... 3-5

Table 3-2. Population persistence*/viability categories (McElhany et al. 2003; McElhany et al. 2006) 3-7

Table 3-3. Criteria guidelines for determining strata and ESU viability (McElhany et al. 2003, 2006) . 3-8

Table 4-1. Evaluation scores for White Salmon fall-run Chinook salmon (McElhany et al. 2004)..... 4-1

Table 4-2. Evaluation scores for White Salmon spring-run Chinook salmon (McElhany et al. 2004) ... 4-2

Table 4-3. Evaluation scores for White Salmon coho salmon (McElhany et al. 2004)..... 4-2

Table 4-4. Evaluation scores for upper Gorge chum salmon (McElhany et al. 2004)..... 4-3

Table 5-1. River miles of salmon and steelhead habitat above and below Condit Dam (NPCC 2004) .. 5-3

Table 5-2. Primary limiting factors for lower Columbia River fall Chinook salmon in the White Salmon River drainage ..... 5-16

Table 5-3. Additional factors potentially limiting anadromous fish (lower Columbia River spring Chinook salmon and coho salmon, Columbia River chum salmon, and middle Columbia River steelhead in the White Salmon River drainage). The primary limiting factors are highlighted in light yellow; factors that may become limiting in the future are highlighted in light gray..... 5-17

Table 6-1. Biological objectives, management strategies, and actions to enhance/reintroduce anadromous salmonid populations and acquire baseline habitat information in the White Salmon River Basin..... 6-8

Table 6-2. Primary biological objectives, management strategies, and actions to improve habitat in the White Salmon River watershed..... 6-11

Table 6-3. Biological objectives, management strategies, and actions to improve habitat in the upper White Salmon River watershed..... 6-12

Table 6-4. Summary table addressing hatchery, harvest and hydrosystem-related recovery strategies and actions..... 6-21

Table 7-1. Summary of potential costs to restore the White Salmon River fish populations and their habitat ..... 7-2

Detailed cost breakdown by specific action..... AIV-2

# Acronyms and Abbreviations

| | |
|---|---|
| **BIA** | Bureau of Indian Affairs |
| **BKD** | Bacterial Kidney Disease |
| **BPA** | Bonneville Power Administration |
| **BMP** | Best Management Practice |
| **CAO** | Critical Areas Ordinance |
| **CBFWA** | Columbia Basin Fish and Wildlife Authority |
| **CEO** | County Environmental Ordinance |
| **cfs** | cubic feet per second |
| **CSMEP** | Collaborative System-wide Monitoring and Evaluation Project |
| **CWT** | Coded wire tag |
| **CUP** | Conditional Use Permits |
| **CR** | Columbia River |
| **CZO** | County Zoning Ordinance |
| **DNA** | Deoxyribonucleic Acid |
| **DPS** | Distinct Population Segment |
| **EDT** | Ecosystem Diagnosis and Treatment |
| **EIS** | Environmental Impact Statement |
| **EPA** | Environmental Protection Agency |
| **ESA** | Endangered Species Act |
| **ESHB** | Engrossed Substitute House Bill |
| **ESU** | Evolutionarily Significant Unit |
| **FCRPS** | Federal Columbia River Power System |
| **FERC** | Federal Energy Regulatory Commission |
| **FMEP** | Fisheries Management and Evaluation Plan |
| **FMP** | Forest Management Plan |
| **FPO** | Floodplain Management Ordinance |
| **GIS** | Geographic Information System |
| **HCD** | Habitat Conservation Plan |
| **HGMP** | Hatchery and Genetic Management Plans |
| **HCD** | Habitat Conservation Plan |
| **ICTRT** | Interior Columbia Technical Recovery Team |
| **IHN** | Infectious Hemotapoietic Necroses |
| **ISAB** | Independent Scientific Advisory Board |
| **km** | kilometer |
| **LCR** | Lower Columbia River |
| **LCFRB** | Lower Columbia Fish Recovery Board |
| **LUMA** | Land Use Management Area |
| **LWD** | Large Woody Debris |
| **LWS** | Little White Salmon |
| **MaSA** | Major Spawning Area |
| **MCR** | Middle Columbia River |
| **MCRFEG** | Middle Columbia River Fisheries Enhancement Group |
| **MEA** | Management Emphasis Area |

| | |
|---|---|
| **MPG** | Major Population Group |
| **NEPA** | National Environmental Policy Act |
| **NFH** | National Fish Hatchery |
| **NMFS** | National Marine Fisheries Service |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NPCC** | Northwest Power and Conservation Council |
| **NPDES** | National Pollution Discharge Elimination System |
| **NPPC** | Northwest Power Planning Council |
| **NRC** | National Research Council |
| **NRCS** | Natural Resources Conservation Service |
| **O&M** | Operation and Maintenance |
| **ODFW** | Oregon Department of Fish and Wildlife |
| **PCSRF** | Pacific Coastal Salmon Recovery Fund |
| **PFMC** | Pacific Fisheries Management Council |
| **PIT** | Passive Integrated Transponder |
| **PNAMP** | Pacific Northwest Aquatic Monitoring Partnership |
| **RCW** | Revised Code of Washington |
| **RM** | River-Mile |
| **RM&E** | Research, Monitoring, and Evaluation |
| **RPA** | Reasonable and Prudent Alternative |
| **SEPA** | State Environmental Policy Act |
| **SMP** | Shorelines Master Plan |
| **SRFB** | Salmon Recovery Funding Board |
| **SSB** | Substitute Senate Bill |
| **TMDL** | Total Maximum Daily Load |
| **TRT** | Technical Recovery Team |
| **TUs** | Thermal Units |
| **UCD** | Underwood Conservation District |
| **URB** | Upriver Bright |
| **USACE** | U.S. Army Corps of Engineers |
| **USFS** | U.S. Forest Service |
| **USFWS** | U.S. Fish and Wildlife Service |
| **USGS** | United States Geographic Survey |
| **VSP** | Viable Salmonid Population |
| **WAGIT** | Washington Gorge Implementation Team |
| **WDF** | Washington Department of Fisheries |
| **WDFW** | Washington Department of Fish and Wildlife |
| **WDNR** | Washington Department of Natural Resources |
| **WDOE** | Washington Department of Ecology |
| **WRIA** | Water Resource Inventory Area |
| **W/LC TRT** | Willamette/Lower Columbia Technical Recovery Team |
| **YN** | Yakama Nation, also Confederated Tribes and Bands of the Yakama Nation |

# Recovery Planning Glossary

**Abundance**: In the context of salmon recovery, unless otherwise qualified, abundance refers to the number of adult fish returning to spawn.

**Adaptive management**: Adaptive management in salmon recovery planning is a method of decision making in the face of uncertainty. An overall implementation plan incorporates a monitoring, evaluation, and feedback framework in which the results of actions become feedback on design and implementation of future actions.

**Anadromous fish**: Species hatched in freshwater, migrate to and mature in salt water, and return to freshwater to spawn.

**Baseline monitoring**: In the context of recovery planning, scientists conduct baseline monitoring to establish historical and/or current conditions to measure progress (or lack of progress).

**Broad-sense recovery goals**: Goals defined in the recovery planning process, that go beyond the requirements for delisting, to address, for example, other legislative mandates or social, economic, and ecological values. Local recovery planning groups usually developed these goals.

**Compliance monitoring**: Determining whether recovery implementation or actions are meeting a specific performance standard, environmental standard, regulation, or law.

**Delisting criteria**: Criteria incorporated into Endangered Species Act (ESA) recovery plans that define both biological viability (biological criteria) and alleviation of the causes for decline (threats criteria based on the five listing factors in ESA section 4[a][1]), and that, when met, would result in a determination that a species is no longer threatened or endangered and can be proposed for removal from the Federal list of threatened and endangered species. These criteria are a National Marine Fisheries Service (NMFS) determination and may include both technical and policy considerations.

**Diel flow**: Flow that occurs during a 24-hour period.

**Distinct Population Segment (DPS)**: A listable entity under the ESA that meets tests of discreteness and significance according to U.S. Fish and Wildlife Service (USFWS) and NMFS policy. A population is considered distinct (and hence a "species" for purposes of conservation under the ESA) if it is discrete from and significant to the remainder of its species based on factors such as physical, behavioral, or genetic characteristics, it occupies an unusual or unique ecological setting, or its loss would represent a significant gap in the species' range.

**Diversity**: All the genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variations could include anadromy *v*. lifelong residence in freshwater, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size,

developmental rate, ocean distribution patterns, male and female spawning behavior, physiology, molecular genetic characteristics, etc.

**Effectiveness monitoring**: Monitoring set up to test cause-and-effect hypotheses about recovery actions: Did the management actions achieve their direct effect or goal? For example, did fencing a riparian area to exclude livestock result in recovery of riparian vegetation?

**ESA recovery plan**: A plan to recover a species listed as threatened or endangered under the U.S. ESA. The ESA requires that recovery plans, to the extent practicable, incorporate (1) objective, measurable criteria that, when met, would result in a determination that the species is no longer threatened or endangered; (2) site-specific management actions that may be necessary to achieve the Plan's goals; and (3) estimates of the time required and costs to implement recovery actions.

**Evolutionarily Significant Unit (ESU)**: A group of Pacific salmon or steelhead trout that is (1) substantially reproductively isolated from other conspecific units and (2) represents an important component of the evolutionary legacy of the species.

**Extinct:** There are no individuals of this former population or species anywhere.

**Extirpated:** Zero population or individuals in a certain area but conspecifics exist elsewhere.

**Factors for decline:** Five general categories of causes for decline of a species, listed in the ESA section 4(a)(1)(b): (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence.

**Functionally extirpated**: A species or population that has been extirpated from an area; although a few individuals may occasionally be found, they are not thought to constitute a population.

**Hyporheic zone**: Area of saturated sediment and gravel beneath and beside streams and rivers where groundwater and surface water mix.

**Implementation monitoring**: An examination to determine whether the responsible public or private implementing entity performed the activity and/or completed it as planned.

**Independent population**: Any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations.

**Indicator**: A variable used to forecast the value or change in the value of another variable.

**Integrated hatchery program**: The purpose of an integrated hatchery program is to increase abundance, while minimizing the genetic divergence of a hatchery broodstock from a naturally spawning population. To maintain the genetic characteristics of a local, natural population among hatchery-origin fish, an integrated program attempts to minimize the genetic effects of domestication. The expected result is a reduction of the genetic risks that hatchery-origin fish may pose to the naturally spawning population.

**Interim regional recovery plan**: A recovery plan intended to lead to an ESA recovery plan but that is not yet complete. These plans might address only a portion of an ESU or lack other key components of an ESA recovery plan.

**Intrinsic potential**: The estimated relative suitability of a habitat for spawning and rearing of anadromous salmonid species under historical conditions inferred from stream characteristics including channel size, gradient, and valley width.

**Intrinsic productivity**: The expected ratio of natural-origin offspring to parent spawners at levels of abundance below carrying capacity.

**Kelts**: Steelhead that are returning to the ocean after spawning and have the potential to spawn again in subsequent years (unlike most salmon, steelhead do not necessarily die shortly after spawning).

**Large Woody Debris (LWD)**: A general term for wood naturally occurring or artificially placed in streams, including branches, stumps, logs, and logjams. Streams with adequate LWD tend to have greater habitat diversity, a natural meandering shape, and greater resistance to flooding.

**Legacy effects**: Impacts from past activities that continue to affect a stream or watershed in the present day.

**Limiting factor**: Physical, biological or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) experienced by the fish that result in reductions in Viable Salmonid Population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Key limiting factors are those with the greatest impacts on a population's ability to reach its desired status.

**Locally developed recovery plan**: State, tribal, regional, and local planning entities throughout the region drafted plans to address the ESA as well as other mandates and recovery needs. Local and regional citizen and business groups were also involved in these planning efforts.

**Maintained status**: Population status in which the population does not meet viability criteria but does support ecological functions and preserve options for ESU/DPS recovery.

**Major Population Group (MPG):** A group of salmonid populations that is geographically and genetically cohesive. The MPG is a level of organization between demographically independent populations and the ESU or DPS.

**Management Unit:** A geographic area defined for recovery planning purposes on the basis of state, tribal or local jurisdictional boundaries that encompass all or a portion of the range of a listed species, ESU or DPS.

**Metrics**: Quantification of a characteristic of a situation or process; for example, the number of natural-origin salmon returning to spawn to a specific location is a metric for population abundance.

**Morphology**: The form and structure of an organism, with special emphasis on external features.

**Natural-origin fish:** Fish spawning and rearing in the wild, regardless of parental origin.

**Parr**: The stage in anadromous salmonid development between absorption of the yolk sac and transformation to smolt before migration seaward.

**Phenotype**: Any observable characteristic of an organism, such as its external appearance, development, biochemical or physiological properties or behavior.

**Piscivorous**: (Adj.) Describes fish that eat other fish.

**Productivity:** The average number of surviving offspring per parent. Used as an indicator of a population's ability to sustain itself or its ability to rebound from low numbers. The terms "population growth rate" and "population productivity" are interchangeable when referring to measures of population production over an entire life cycle. Often expressed as the number of recruits (adults) per spawner or the number of smolts per spawner.

**Recovery domain**: A NMFS-defined administrative unit for recovery planning based on ESU boundaries, ecosystem boundaries, and existing local planning processes. Recovery domains may contain one or more listed ESUs.

**Recovery goals**: Goals incorporated into a locally developed recovery plan, which may include recovery, delisting, reclassification, and/or other goals. Broad-sense goals are a subset of recovery goals.

**Recovery plan supplement**: A NMFS supplement to a locally developed recovery plan that describes how the plan addresses ESA requirements for recovery plans. The supplement also proposes ESA delisting criteria for the ESUs addressed by the plan, since a determination of these criteria is a NMFS decision.

**Recovery scenarios:** Scenarios that describe a target status for each population within an ESU, generally consistent with Technical Recovery Team (TRT) recommendations for ESU viability.

**Redd**: A female salmonid constructs a nest, or redd, in streambed gravels where she deposits her eggs and males fertilize them.

**Recovery strategy**: Statements that identify the assumptions and logic-the rationale-for the species' recovery program.

**Riparian area**: Area with distinctive soils and vegetation between a stream or other body of water and the adjacent upland.

**Salmonid**: Fish of the family *Salmonidae*, including salmon, trout, char, grayling, and whitefish. In general usage, the term usually refers to salmon, trout, and char.

**Segregated hatchery program**: The intent of a segregated hatchery program is to maintain a genetically distinct hatchery population. The only way to reduce risk (genetic and ecological) to natural populations from segregated programs is to minimize the contribution of hatchery fish to natural spawning.

**Smolt**: A juvenile salmonid that is undergoing physiological and behavioral changes to adapt from freshwater to saltwater as it migrates toward the ocean.

**Spatial structure**: Characteristics of a fish population's geographic distribution. Current spatial structure depends upon the presence of fish, not merely the potential for fish to occupy an area.

**Stakeholders**: Agencies, groups, or private citizens interested in or affected by recovery planning and/or actions.

**Technical Recovery Team (TRT)**: NMFS convenes work groups, the TRTs, to develop technical products related to recovery planning. Planning forums unique to specific states, tribes, or regions both complement and use TRTs and other technical products to identify recovery actions.

**Threats**: Human activities or natural events (e.g., road building, floodplain development, fish harvest, hatchery influences, volcanoes) that cause or contribute to limiting factors. Threats may exist in the present or be likely to occur in the future.

**Viability criteria**: NMFS appointed TRTs to define criteria to describe a VSP based on the biological parameters of abundance, productivity, spatial structure, and diversity. NMFS and others use these viability criteria as technical input into the recovery planning process and provide a technical foundation for development of biological delisting criteria.

**Viability curve**: A curve describing combinations of abundance and productivity that yield a particular risk or extinction level at a given level of variation over a specified time frame.

**Viable Salmonid Population (VSP)**: An independent population of Pacific salmon or steelhead trout that has a negligible risk of extinction over a 100-year time frame.

**VSP parameters**: Abundance, productivity, spatial structure, and diversity. These describe characteristics of salmonid populations that are useful in evaluating population viability. See NOAA Technical Memorandum NMFS-NWFSC-42, *viable salmonid populations and the recovery of evolutionarily significant units*, McElhany et al., June 2000.

# Executive Summary

The Endangered Species Act (ESA) of 1973 requires National Oceanic and Atmospheric Administration (NOAA)'s National Marine Fishers Service (NMFS) to develop recovery plans for species listed under the Act. The purpose of recovery plans is to identify actions needed to restore threatened and endangered species to the point that they are again self-sustaining elements of their ecosystems and no longer need the protections of the ESA. Recovery plans are not regulatory documents; they are guidance for anyone involved in species recovery efforts as well as for the various state, Federal, tribal, and local entities whose activities and jurisdictions may affect endangered species. A recovery plan provides a roadmap for restoring a listed species or population to biological viability and greater likelihood of long-term survival.

This is a plan for re-establishing the White Salmon River populations of lower Columbia River (LCR) Chinook salmon, LCR coho salmon, Columbia River (CR) chum salmon, and MCR steelhead. The Plan aims for these populations to contribute to the conservation and survival of their respective Evolutionarily Significant Units (ESUs)/Distinct Population Segments (DPSs)[1] (Table ES-1).

The White Salmon River fall and spring Chinook salmon are included in the LCR Chinook salmon (*Oncorhynchus tshawytscha*) ESU, which NMFS listed as threatened on March 24, 1999 and reconfirmed June 28, 2005. The ESU includes all naturally spawned populations of Chinook salmon in the CR and its tributaries from its mouth at the Pacific Ocean upstream to a transitional point east of Hood River in Oregon and the White Salmon River in Washington. The White Salmon River spring Chinook salmon are considered extirpated (Good et al. 2005; Myers et al. 2006).

The White Salmon River coho salmon are part of the LCR coho salmon (*Oncorhynchus kisutch*) ESU, which NMFS listed as threatened on June 28, 2005. The ESU includes all naturally spawned coho salmon populations in the CR and its tributaries from the mouth of the CR to a transitional point east of the Hood and White Salmon Rivers. The White Salmon River coho salmon are considered extinct (Good et al. 2005; Myers et al. 2006).

The White Salmon chum salmon are part of the CR chum salmon *(Oncorhynchus keta*) ESU, which NMFS listed as threatened on March 25, 1999. The CR chum salmon ESU includes all naturally spawning populations in the CR and its tributaries in Washington and Oregon. Presently, all CR chum salmon spawning populations are located downstream of Bonneville Dam. Annual fish passage reports (U.S. Army Corps of Engineers (USACE), 2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008) for Bonneville Dam provided data that adult

[1] An 'evolutionarily significant unit' (ESU) of Pacific salmon (Waples 1991) and a 'distinct population segment' (DPS) of steelhead (71 FR 834, January 5, 2006) are considered to be 'species,' as defined in section 3 of the ESA.

chum salmon continue to pass upstream of Bonneville Dam, with adult counts averaging 139 and ranging from a low of 46 to high of 411 from 2000 to 2008.

The White Salmon River historically included a population of MCR steelhead (*Oncorhynchus mykiss*). The MCR steelhead DPS is made up of steelhead populations in Oregon and Washington tributaries of the CR upstream of the Hood and Wind River systems, up to and including the Yakima River. The White Salmon steelhead population is considered "functionally extirpated" for the following reasons: the population's current lack of access to sufficient habitat to support sustained natural production; the presence of a large in-basin hatchery release program below the dam that uses out-of-basin broodstock (ICTRT 2007a); and only a few individual fish may still be present from the original White Salmon population. Functionally extirpated populations are those with so few remaining numbers that there are not enough fish or habitat in suitable condition to support a fully functional population.

**Table ES-1. ESA listed DPS/ESU in the White Salmon River**

| Species | ESU/DPS | Status | Federal Register Notice | |
|---|---|---|---|---|
| Chinook salmon (*Oncorhynchus tshawytscha*) | LCR Chinook salmon | Threatened | 70 FR 37160 | 6/28/2005 |
| Coho salmon (*O. kisutch*) | LCR coho salmon | Threatened | 70 FR 37160 | 6/28/2005 |
| Chum salmon (*O. keta*) | CR chum salmon | Threatened | 70 FR 37160 | 6/28/2005 |
| Steelhead (*O. mykiss*) | MCR steelhead | Threatened | 71 FR 834 | 1/5/2006 |
| Critical Habitat Designation | LCR Chinook salmon, CR chum salmon, LCR coho salmon, MCR steelhead | | 70 FR 52630 | 9/2/2005 |

## Context of Plan Development

This recovery plan provides direction for potential recovery of the White Salmon River's historical salmon and steelhead populations. This plan builds on the past and current efforts of the many parties currently working to rebuild populations and improve their habitat. This approach reflects NMFS's belief that it is critically important to base ESA (4f) recovery plans on the many state, regional, tribal, local, and private conservation efforts that are already underway. NMFS initiated a process that incorporated input from the Yakama Nation (YN), Washington Department of Fish and Wildlife (WDFW), Klickitat County, the Washington State Governor's Salmon Recovery Office, other Federal and state agencies, local governments, and the public. That process produced the White Salmon Recovery Plan.

Currently, there are 18 ESA-listed species of Pacific salmon and steelhead in the Pacific Northwest. For the purpose of recovery planning for these species, NMFS Northwest Region

designated five geographically based "recovery domains": Interior Columbia, Willamette/lower Columbia, Puget Sound and Washington Coast, Oregon Coast and the Southern Oregon/Northern California Coast. The White Salmon watershed is in an area where the Interior Columbia and Willamette/lower Columbia recovery domains overlap.

In each domain, NMFS has worked with state, tribal, and local entities and other Federal entities to develop planning forums that build to the extent possible on ongoing, locally led recovery efforts. NMFS defined "Management Units" based on jurisdictional boundaries as well as areas where local planning efforts were underway. In the LCR there are three management units for the LCR ESUs, these are 1) Oregon; 2) Washington; 3) the White Salmon River ESUs (not including the Steelhead DPS). In the MCR steelhead recovery domain the management units are 1) Oregon; 2) Washington Gorge, which, in turn, NMFS subdivided into three planning areas, White Salmon, Klickitat, and Rock Creek; 3) Yakima Basin; 4) Southeast Washington.

NMFS intends to incorporate the White Salmon Watershed Recovery Plan as an appendix to both the LCR Salmon and Steelhead Recovery Plan and the MCR Steelhead Recovery Plans since the White Salmon River watershed has ESA-listed species in both of the two NMFS Recovery Domains.

For each domain, NMFS appointed a team of scientists, nominated for their geographic and species expertise, to provide a solid scientific foundation for recovery plans. The charge of each TRT was to define ESU/DPS structures, develop recommendations on biological viability criteria for each ESU or DPS and its component populations, provide scientific support to local and regional recovery planning efforts, and provide scientific evaluations of proposed recovery plans. The Willamette/lower Columbia Technical Recovery Team (W/LC TRT) provided technical support for the LCR ESUs recovery plan, while the Interior Columbia Technical Recovery Team (ICTRT), provided technical support for the White Salmon Steelhead Recovery Plan. These TRTs included biologists from NMFS, states, tribal entities, and academic institutions.

All the TRTs used the same biological principles for developing their recommendations for ESU/DPS and population viability criteria-criteria to be used, along with criteria based on mitigation of the factors for decline, to determine whether a species has recovered sufficiently to be downlisted or delisted. A NMFS technical memorandum, *Viable Salmon Populations and the Recovery of Evolutionarily Significant Units* describes these principles (McElhany et al. 2000). The memorandum defines VSPs in terms of four parameters: abundance, population productivity or growth rate, population spatial structure, and diversity. A viable ESU/DPS is naturally self-sustaining, with a high probability of persistence over a 100-year time period. Each TRT made recommendations using the VSP framework and based on data availability, the unique biological characteristics of the ESUs/DPSs and habitats in the domain, and the members' collective experience and expertise. Although NMFS has encouraged the TRTs to develop regionally specific approaches for evaluating viability and identifying factors limiting recovery, all the TRTs are working from a common scientific foundation.

## Physical Setting

The White Salmon watershed drains approximately 386 square miles in south central Washington (Figure ES-1). The river begins along the south slope of Mt. Adams and flows south 45 miles to enter the CR at Underwood, Washington at river-mile (RM) 168.3. White Salmon River salmon populations pass one mainstem CR dam, Bonneville Dam, during their migration to and from the Pacific Ocean.

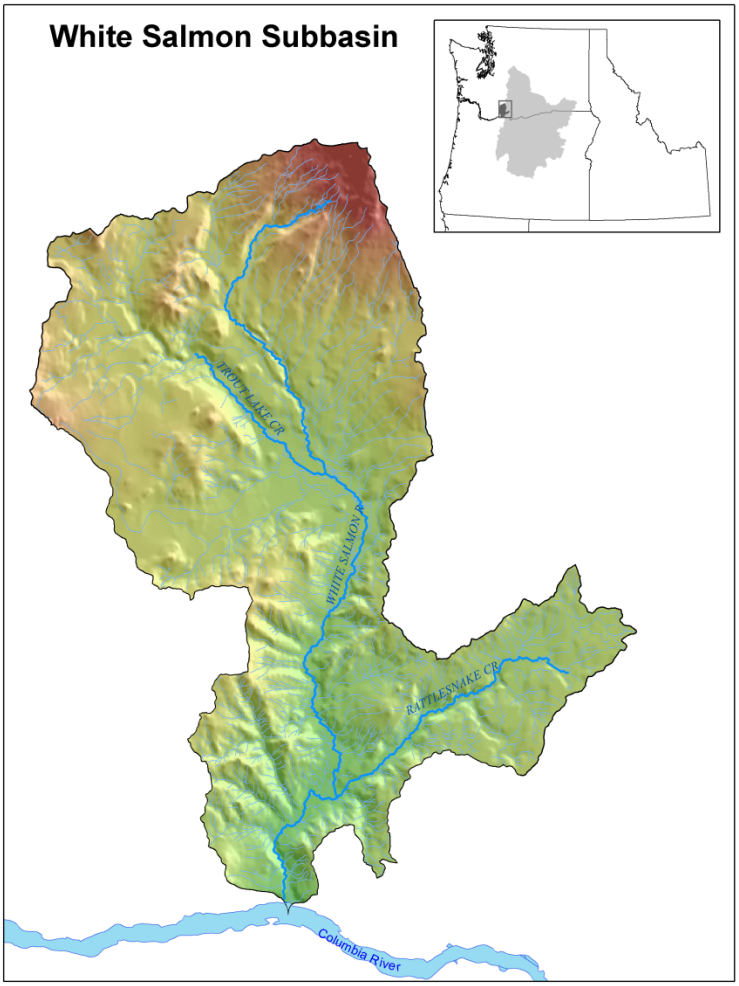


**Figure ES-1. White Salmon watershed in Washington State (NPCC 2004)**

Salmon and steelhead production in the White Salmon River watershed dropped significantly in the early 1900s after construction of Condit Dam at RM 3.3 on the White Salmon River. Condit Dam's original owners built a fish ladder; however, high flows twice destroyed the ladder and subsequent owners did not reconstruct it after 1919.

Fish passage, either through removal of the dam or installation of upstream and downstream fish passage facilities has been under evaluation as part of the Federal Energy Regulatory Commission (FERC) re-licensing process. PacifiCorp Power, the owner of Condit Dam,

rejected the proposal to install fish passage facilities and is currently removing the dam. This Plan includes a proposal to establish or re-establish natural production of salmon and steelhead in the White Salmon watershed, based on natural re-colonization of the habitat above the dam after removal. Recovery actions may also include implementation of hatchery augmentation of populations and/or hatchery preservation of genetic stocks.

The White Salmon watershed is part of both of Washington State's LCR salmon recovery domain and the MCR Steelhead Recovery sub-domain. White Salmon River is within parts of Skamania, Yakima, and Klickitat counties. In addition, the watershed falls within the state's Water Resource Inventory Area (WRIA) 29b. Half of the watershed lies within the Gifford Pinchot National Forest and supports timber production and recreational uses.

The White Salmon watershed contains lands the YN ceded to the United States in the Treaty of June 9, 1855. Within this area, the Tribe reserves the right "to hunt and fish at all usual and accustomed places." An in-lieu fishing site is located at the mouth of the White Salmon River, allowing tribal fishers to launch boats in an enclosed area and move out into the C R to their usual and accustomed fishing grounds.

### Ecosystem Conditions

Condit Dam, at RM 3.3 on the mainstem White Salmon River, blocked all anadromous fish migration to historical habitats in the upper drainage. Dam removal began on October 26, 2011. Historical operations at Condit Dam altered flows in the lower White Salmon River, causing flows to drop to as low as 15 cubic feet per second (cfs) in the 1.1-mile bypass reach. Average natural flows are about 700 cfs. Power peaking at the dam affected the river system, causing diel flow variations and impairing watershed processes, such as the transportation of spawning gravels and Large Woody Debris (LWD) to areas downstream of the project (NPCC 2004). The lack of sediment transport into these reaches has affected habitat conditions downstream of Condit Dam. Conditions in the lower river below the former location of Condit Dam and under the former reservoir are anticipated to change substantially in response to the removal of the dam and subsequent stabilization actions.

Upstream of Condit Dam, the White Salmon River has a relatively constant natural flow pattern because of glacial melt and a large water storage capacity. Tributary stream flows drop to low levels in the summer and peak in the winter. Upstream of the dam, Northwestern Lake occupied the portion of the river between Buck Creek and the dam. Removal of the dam is exposing the lakebed. The coarseness of substrate sediment in the former lakebed is variable, with coarser material deposited at the top of the former reservoir and finer material downstream. Riparian vegetation is currently non-existent, and banks will be unstable until restoration actions are completed.

The extent of time it will take to re-establish channel and watershed processes in the former lakebed and the area below the former dam is unknown. Upstream of the former Northwestern Lake, some tributaries have warm water temperature, sparse riparian vegetation, high nutrient levels, low instream LWD abundance, and poor pool volume and frequency. Biologists have documented fish-borne diseases, Bacteria Kidney Disease (BKD) and Black Spot in the watershed (section 5.6, Predation, Competition and Disease).

## Populations and Major Population Groups

Historically, MCR steelhead, likely ranged up the White Salmon River to the falls at RM 16 and into Buck, Spring, Indian, and Rattlesnake creeks (NPCC 2004). Based on accessible spawning habitat and a combination of notes, diary logs, and interviews (Lane and Lane Associates 1981), biologists assume that spring Chinook salmon and coho salmon were present historically in the watershed. Husum Falls, RM 7.6, may have blocked fall Chinook salmon migration and created a partial barrier for steelhead and coho salmon (NPCC 2004). All anadromous fish passage to historical habitats in the White Salmon drainage above RM 3.3 ended after construction of Condit Dam and the failure of the fish ladder in 1919. Now that Condit Dam has been removed, populations are anticipated to repopulate the watershed.

Presently, the historical spring Chinook salmon population is considered extirpated (Good et al. 2005; Myers et al. 2006), the historical steelhead population is considered functionally extirpated (ICTRT 2007b), the historical coho salmon population is considered extinct (Good et al. 2005; Myers et al. 2006), and the historical fall Chinook salmon population is considered at very high risk of extinction (ICTRT 2006; McElhany et al. 2004; Ford et al. 2011).

## Biological Viability Criteria

### *White Salmon River fall Chinook salmon*

The W/LC TRT gave the White Salmon River fall Chinook salmon population a weighted average extinction risk score of 0.86 on a scale of 0 to 4, with 0 = extirpation or nearly so, and 4 = very low extinction risk. This suggests that the population is at a very high risk of extinction (McElhany et al. 2004). Most W/LC TRT members considered hatchery strays to heavily influence the in-river fall-run Chinook salmon population, although some team members included the Spring Creek National Fish Hatchery (NFH) in their diversity evaluation as a potential source for re-establishing a native-run.

### *White Salmon River spring Chinook salmon*

The W/LC TRT rated the White Salmon River spring-run Chinook salmon with a weighted average extinction risk score of 0.07, indicating the population is likely extirpated. The team concluded that any population that may have been historically present is currently extirpated because of construction of Condit Dam.

### *White Salmon River coho salmon*

McElhany et al. weighted the White Salmon coho salmon population with an average extinction risk score of 0.39, indicating that the population is likely very near extinction (2004) or extinct (Good et al. 2005).

### *White Salmon River chum salmon*

The lower Columbia Fish Recovery Board (LCFRB) identified the entire population of upper Gorge Chum salmon, which includes the historical population of chum salmon spawning in the White Salmon River, to have a very low viability (LCFRB 2004). Bonneville Reservoir inundates most of historical habitat for this population. T

### *White Salmon River steelhead*

The ICTRT classified the White Salmon River steelhead population as functionally extirpated (ICTRT 2008). The ICTRT considers extirpated populations as those entirely cut off from anadromy. Functionally extirpated populations are those with so few remaining that there are not enough fish or habitat in suitable condition to support a fully functional population. The ICTRT identified one historical Major Spawning Area (MaSA) within the White Salmon watershed. A few individuals from the original population may have been spawning in the reach below Condit Dam and some evidence suggests that resident *O. mykiss* may have retained anadromous potential (Allen et al. 2006a and 2006b; Allen, personal communication, 2008).

## Limiting Factors

Chapter 5 discusses in-watershed and out-of-watershed factors and related threats influencing the viability of the White Salmon River salmon and steelhead populations. NMFS defines limiting factors as the biological and physical conditions that limit a species' viability - e.g., high water temperature and defines threats as those human activities or naturally induced actions that cause the limiting factors. For example, removing the vegetation along the banks of a stream (the threat) can cause higher water temperatures (the limiting factor), because the stream is no longer shaded. Analysis of limiting factors and threats across the species' entire life cycle forms the basis for designing recovery strategies and actions.

"Threats" are present or likely anthropogenic activities or natural events that cause or contribute to the factors limiting the species' recovery. The development of threat reduction strategies can be complex, especially when human activities that pose threats to the species satisfy otherwise "beneficial" societal or cultural functions (e.g., flow management may threaten the species by reducing summer flows an increasing water temperatures, but the flow management may support an agricultural economy or protect human safety and property through flood prevention). In such circumstances, it is desirable to manage a threat in such a way that it minimizes or eliminates the negative impacts to the species, while retaining essential societal or cultural functions.

## Blocked Passage

Until recently, blockage of fish passage upstream of Condit Dam was the single greatest factor limiting salmon abundance and productivity in the White Salmon River watershed. When the dam was in place, fall Chinook salmon accessed only a small percentage of their historical spawning and rearing habitat in the watershed. While the area directly below the dam was not "blocked," the hydraulics and substrate composition of this habitat had changed rendering it unsuitable for spawning. With the removal of Condit Dam, the hydraulics and substrate composition is evolving and now can support natural spawning though the habitat and substrates directly influence by the Bonneville Dam pool continue to limit spawning. Bonneville Dam has also flooded 80 percent of the spawning area used by chum salmon (NPCC 2004).

### Tributary Habitat

The upstream habitats are currently being re-occupied by anadromous fish now that access has been provided. Spawning and rearing habitat upstream of the dam may eventually limit anadromous salmonid population abundance in the White Salmon River. Opportunities exist to improve upstream habitats to support future population levels. Sections 5.2, Freshwater Habitat and 6.2, Freshwater Habitat Strategies and Actions, for further discussion on tributary habitat.

### Hatchery Practices and Releases

#### *Chinook salmon*

Most of the fish spawning naturally in the White Salmon River were assumed to be hatchery-origin tule fall Chinook salmon based on CWT recoveries. Spring Creek NFH began marking all of its hatchery production in 2004 and as a result, recent spawning ground surveys have shown that the majority of the tule fall Chinook salmon returning to the White Salmon River are of natural origin (Roler 2011). Spring Creek NFH tule fall Chinook salmon were originally derived from White Salmon tule fall Chinook salmon and are anticipated to contribute to natural production now that Condit Dam has been removed. Stray upriver bright (URB) hatchery fall Chinook salmon may adversely affect productivity of the tule fall Chinook salmon in the White Salmon River. These hatchery-origin strays are from releases at the Little White Salmon (LWS) NFH, located 3 miles downstream from the White Salmon River, and other releases in and below the Bonneville Pool. No facility releases hatchery-produced Chinook salmon into the White Salmon River watershed.

#### *Coho salmon*

Biologists found coho salmon from past releases by the LWS NFH to stray into the White Salmon watershed. Coho salmon releases from LWS NFH ended in 2004. Biologists consider these strays along with releases from other upstream Columbia Basin hatchery programs as the source of naturally spawning coho salmon in the White Salmon River.

#### *Chum salmon*

There are no hatchery chum salmon programs releasing fish above Bonneville Dam, although some incubated at the Washougal Hatchery and released as fry into Duncan Creek may be among those that ascend the Bonneville ladders.

#### *Steelhead*

Releases of Skamania stock winter steelhead and summer steelhead may limit the diversity of any naturally produced winter steelhead in the watershed. Scientists consider neither as part of the LCR or MCR steelhead DPSs. Fisheries managers terminated the releases of Skamania stock hatchery steelhead in 2010 in anticipation of breaching Condit Dam.

### Harvest

Harvest currently does not limit the abundance or diversity of White Salmon River populations of steelhead, spring Chinook salmon, coho or chum salmon. All of these populations are extirpated or functionally extirpated (Good et al. 2005; ICTRT 2007b). Any

coho salmon, chum salmon, steelhead, and spring Chinook salmon found in the White Salmon River are strays from other basins. To protect naturally produced coho salmon, spring Chinook salmon, fall Chinook salmon, and steelhead in the White Salmon River, sport fisheries may only retain hatchery fish that are adipose fin-clipped and release all unmarked salmon and steelhead https://fortress.wa.gov/dfw/erules/efishrules/ (accessed January 3, 2013). Ocean and mainstem fisheries heavily harvest fall Chinook salmon, and harvest rates are likely to affect the rate of population growth once additional habitat in the watershed becomes available (section 5.4, Harvest, for further discussion).

### Federal Columbia River Hydrosystem

Much of the mainstem Columbia and Snake rivers' current conditions are altered compared to historic conditions. The development of hydropower and water storage projects within the CR Basin have resulted in the inundation of many mainstem spawning and shallow-water rearing areas (e.g., loss of spawning gravels and access to spawning and rearing areas); altered water quality (e.g., reduced spring turbidity levels), water quantity (e.g., seasonal changes in flows and consumptive losses resulting from use of stored water for agricultural, industrial, or municipal purposes), water temperature (e.g., including generally warmer minimum winter temperatures and warmer maximum summer temperatures), water velocity (e.g., reduced spring flows and increased cross-sectional areas of the river channel), food (e.g., alteration of food webs, including the type and availability of prey species), and safe passage (e.g., increased mortality rates of migrating juveniles and steelhead kelts) (Williams et. al 2005; Ferguson et. al 2005).

Model studies indicate that the hydrosystem has decreased the delivery of suspended particulate matter to the LCR and estuary by about 40 percent (as measured at Vancouver, Washington) and has reduced fine sediment transport by 50 percent or more (Bottom et al. 2005). Overbank flow events, important to habitat diversity, have become rare, in part because flow management and irrigation withdrawals prevent high flows and in part because diking and revetments have increased the "bankfull" flow level (from about 18,000 to 24,000 m3/s). The dynamics of estuarine habitat have changed in other ways relative to flow. With increasing flow, the availability of shallow (between 10 cm and 2 m depth), low-velocity (less than 30 cm/s) habitat now appears to decrease at a steeper rate than during the 1880s, and the flow absorption capacity of the estuary appears to have declined.

The CR Estuary Module, at http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Estuary-Module.cfm (accessed April 11, 2012) provides more information on factors that may limit viability of anadromous salmonids in the CR Estuary.

### Predation, Competition and Disease

Because of Bonneville Dam's reservoir habitat, the abundance of predatory native and exotic fishes in the lower river has increased. Primary predators of juvenile salmonids in the CR include northern pikeminnow, smallmouth bass, and walleye. Terns, cormorants, and sea lions also consume large numbers of salmonids.

Hatchery steelhead juvenile releases into the White Salmon River probably led to competition with any natural origin smolts produced below the former Condit Dam, but hatchery managers have terminated these releases. Hatchery adults that stray into the White

Salmon River may compete for spawning and rearing habitat. Spawning of later returning URB fall Chinook salmon can reduce the productivity of naturally spawning tule fall Chinook salmon through redd superimposition.

Researchers have reported BKD and Black Spot throughout the White Salmon watershed (Allen et al. 2006a, 2006b). Now that Condit Dam has been removed, diseased fish may introduce other pathogens and diseases into the watershed. The effects of disease on current or any potential future populations are unknown.

### Ocean Conditions

The effects of ocean conditions on abundance of Pacific salmon and steelhead vary among species and populations within species. Migration patterns in the ocean may differ dramatically and expose different stocks to different conditions in different parts of the ocean. Ocean survival of salmonids has been dramatically affected by widespread changes in ocean conditions; smolt-to-adult survival rates generally vary 10-fold between good and bad years.

### Climate Change

Climate change represents a potentially significant threat to recovery of White Salmon River salmon and steelhead populations. Changes in climate may adversely affect salmon and steelhead by exacerbating existing problems with water quantity (e.g., lower summer stream flow) and water quality (e.g., higher summer water temperatures) and could be detrimental to many populations of salmonids and native fish species throughout the CR Basin. Changing conditions could also affect salmonid health and survival in the ocean through a variety of mechanisms, including increased ocean temperatures, increased stratification of some waters, changes in the upwelling season, shifts in the distribution of salmonids, long-term variability in winds and ocean temperatures, increased acidity, and increased atmospheric and oceanic variability (NMFS 2008a, Supplemental Comprehensive Analysis Chapter 5), available at http://www.nwr.noaa.gov/Salmon-Hydropower/Columbia-Snake-Basin/upload/Final_SCA_Ch1_7.pdf (accessed April 11,2012). See also ISAB 2007.

### Recovery Goals and Criteria

The primary goal of this plan is to restore White Salmon River salmon and steelhead populations to viable status. McElhany et al. (2000) defines a VSP as an independent population that has negligible risk of extinction over a 100-year timeframe.

The visions, goals, and actions of many of the parties involved in the White Salmon recovery planning process may go beyond ESA delisting. These visions for broad-sense recovery incorporate ESA delisting goals. During the process of achieving broad-sense recovery goals, NMFS could delist White Salmon River salmon and steelhead. Broad-sense recovery goals incorporate many local and traditional uses, including those associated with rural and Native American values, which are important in the Pacific Northwest.

### Biological Viability Criteria

One of the main tasks assigned to the TRTs was to develop biologically based criteria for ESA-listed salmon and steelhead. Viability criteria identify characteristics and conditions that, when met, would describe viable populations and a viable ESU or DPS.

The TRTs based their approaches to recovery on guidance from the NMFS Technical Memorandum *Viable Salmonid Populations and the Recovery of Evolutionarily Significant* Units (McElhany et al. 2000). This memorandum provides general direction for setting viability objectives at the ESU/DPS and component population levels. In their VSP guidelines, McElhany et al. (2000) recommend that a viable DPS population should be large enough to:

- Have a high probability of surviving variation observed in the past and expected future
- Be resilient to environmental and anthropogenic disturbances
- Maintain genetic diversity
- Support/provide ecosystem functions

NMFS organized the viability guidelines provided by McElhany et al. (2000) around four major considerations: abundance, productivity, spatial structure, and diversity. ESU-level viability criteria consider the appropriate distribution and characteristics of component populations to maintain the ESU/DPS in the face of longer-term ecological and evolutionary processes (ICTRT 2005a). NMFS adopted the ICTRT and W/LC TRT-defined viability criteria as the biological criteria for delisting of the ESUs and DPS that include the listed White Salmon populations discussed in this Plan.

### Recovery Strategy and Actions

Chapter 6 describes the recovery strategies for the White Salmon River salmon and steelhead populations. The recovery strategies for each population contain three key components: 1) reintroducing naturally produced salmon and steelhead into historical habitat upstream of the former Condit Dam, 2) improving and increasing habitat for salmon and steelhead production downstream of Buck Creek, 3) improving habitat upstream of Buck Creek in anticipation of the growth of anadromous populations. The Plan also recommends that harvest or hatchery actions do not impede efforts to improve salmon and steelhead viability.

Table ES-2 lists the strategies and actions proposed as an integrated approach to address limiting factors and threats to salmon and steelhead and achieve broad-sense goals in four categories: freshwater habitat, hatcheries, harvest, and hydrosystem operations.

The Plan also proposes a number of actions focused on data gathering and analysis. These efforts are needed to monitor the current population status and habitat conditions and to improve the likelihood that efforts to reintroduce salmon and steelhead in the White Salmon are efficient and successful.

Together, NMFS expects the proposed strategies and actions to increase abundance, productivity, spatial structure, and diversity of White Salmon River salmon and steelhead.

The strategies and actions build from past and current efforts to restore passage and improve habitat conditions in the watershed.

### *Introduction/Restoration of Anadromous Salmonid Populations*

In anticipation of the removal of Condit Dam, the White Salmon Working Group, made up of Federal, state, and tribal fisheries managers, as well as representatives of PacifiCorp (Condit Dam operators), developed several options for the reintroduction of salmon and steelhead into the White Salmon River. The group fleshed out each option with a description of the biological basis for the approach, operational and maintenance needs, and monitoring and evaluation needs. For details about the options and considerations, see Appendix I.

#### Fall Chinook salmon Reintroduction Plan Options

1. Salvage adipose-fin present Coded-Wire-Tag (CWT) - negative tule fall Chinook salmon from the White Salmon River in the fall of 2010 to start tule fall Chinook salmon restoration.
2. The Spring Creek NFH would spawn adults and rear eggs. The hatchery would acclimate and release the resulting juveniles at White Salmon Ponds.
3. No salvage effort in the White Salmon River or at Spring Creek NFH.
4. Salvage adipose-fin present CWT - negative tule fall Chinook salmon returning to the White Salmon River and outplant above Condit Dam prior to removal.

The White Salmon Working Group recommended the outplant Option 4 because they believed habitat is currently available above Condit Dam that can support natural spawning tule fall Chinook salmon. The White Salmon Working Group completed the salvage of native fish in late summer and early fall of 2011 prior to breaching the dam.

#### Spring Chinook salmon Reintroduction Plan Options

1. Natural colonization, i.e. no reintroduction efforts from outside sources.
2. Wild Klickitat spring Chinook salmon as brood source for juvenile release into the White Salmon River. Eggs collected and reared at Klickitat Hatchery, juveniles acclimated and released at White Salmon Ponds.
3. Klickitat Hatchery spring Chinook salmon as brood source for juvenile releases into upper White Salmon River (from Klickitat Hatchery thinning release or other surplus juveniles).
4. Klickitat Hatchery integrated stock spring Chinook salmon as brood source for juvenile release into White Salmon River, in future years (broodstock source would be hatchery-reared offspring of wild fish).
5. Transport surplus Klickitat Hatchery adults to White Salmon River.
6. Trap and transport Klickitat wild adults to White Salmon River.
7. Monitor natural escapement and production for 4-5 years then evaluate need and suitability of Option 4.

The White Salmon Working Group recommended Option 7. Under this option Working Group members propose to monitor escapement of spring Chinook salmon into the upper White Salmon River, including the proportion of Carson stock hatchery spring Chinook salmon on the spawning grounds. The White Salmon Working Group will also monitor spring Chinook salmon smolt production in the upper White Salmon. The 4-5 year monitoring period will determine if natural production is occurring and the source of that production. The monitoring period will also allow time for the development of the Klickitat Hatchery integrated spring Chinook salmon program and determine whether production capacity at this facility is available. The White Salmon Working Group considered the Klickitat Hatchery spring Chinook salmon program the best source of broodstock for reintroduction, even though it is not part of the LCR Chinook salmon ESU. The two nearest populations of spring Chinook salmon within the LCR ESU are in the Lewis River in Washington and the Sandy River in Oregon. Each of these basins have spring Chinook salmon hatchery programs, but reintroduction efforts in the Lewis River Basin require current local production in the Lewis River is needed for reintroduction efforts in that basin, while broodstock collection and funding shortfalls constrain production in the Sandy River. The result is the unavailability of a suitable source of LCR spring Chinook salmon to support the reintroduction efforts in the White Salmon River.

### Coho salmon Reintroduction Plan Options

1. Natural re-colonization, i.e., no reintroduction efforts from outside sources.
2. Juveniles from Washougal and/or Bonneville/Cascade hatcheries released into White Salmon River.
3. Collection of wild adult broodstock in Klickitat River with spawning and rearing at hatchery facility and juvenile release in White Salmon River.
4. Collection of wild adult broodstock in White Salmon River with spawning and rearing at hatchery facility and juvenile release in White Salmon River.
5. Monitor natural escapement and production for 4-5 years then evaluate need and suitability of Options 2, 3, or 4.

The White Salmon Working Group decided on Option 5 for coho salmon. As described for spring Chinook salmon, White Salmon Working Group members propose to monitor escapement, hatchery- and natural-origin coho salmon on the spawning grounds, and juvenile production in the White Salmon River watershed. Sources of stray hatchery coho salmon include releases from Bonneville Hatchery and releases into the Klickitat and the Umatilla river basins. All of these releases derive from hatchery programs that are part of the LCR coho salmon ESU. A recovery team will use the results of the monitoring to determine future reintroduction activities.

### Chum salmon Reintroduction Plan Options

1. Natural re-colonization, i.e., no reintroduction efforts from outside sources.
2. Active adult outplanting in years after Condit Dam removal.

3. Active stocking of juvenile chum salmon or outplanting of eggs in egg baskets and hatch boxes via WDFW's Washougal Hatchery or Willard NFH.

4. Initiate provisional hatchery program for chum salmon using existing US Fish and Wildlife Service (USFWS) hatcheries (White Salmon Ponds) for spawning and subsequent outplanting using chum salmon captured at Bonneville Dam.

The White Salmon Working Group decided on Option 1 for chum salmon. The group chose this option because of the uncertainty regarding the status of chum salmon above Bonneville Dam. This option calls for expanded spawning ground surveys in the Bonneville Pool using the mainstem chum salmon spawning habitat criteria developed for the population below Bonneville Dam. Those conducting surveys should focus in the lower reaches of suitable tributaries and include habitat suitability assessments for the reservoir and the tributaries.

### Steelhead Reintroduction Plan Options

1. Natural re-colonization, i.e., no reintroduction efforts from outside sources.

2. Wild donor from local watershed as brood source for juvenile release into the White Salmon River. Eggs collected and reared at suitable hatchery, juveniles acclimated and released at White Salmon Ponds.

3. White Salmon resident *O. mykiss* as brood source, with locally suitable anadromous wild donor stock spawned for juvenile release into upper White Salmon River.

4. White Salmon steelhead captive brood program using captured outmigrating juveniles.

5. White Salmon steelhead kelt reconditioning. Recondition local spawners to enhance survival.

Based on the potential to re-establish natural production of steelhead in the watershed, the White Salmon Working Group decided Option 1, natural re-colonization, was the best approach. The indication that the (resident) population of *O. mykiss* in the White Salmon River above the former Condit Dam still produces smolts, even though the construction of Condit Dam and the end of passage in 1919 eliminated anadromy, was the basis of the group's decision. Recent monitoring in the White Salmon River above Condit Dam has identified *O. mykiss* juveniles displaying smolt behavior and morphology. Passive Integrated Transponder (PIT)-tagged juveniles have been detected passing Bonneville Dam, with one being recovered at the tern colony on East Sand Island (B. Allen personal communication, 2007). In addition, biologists detected an individual juvenile *O. mykiss* PIT-tagged above Condit Dam in September 2004 at 98 mm and again as an adult ascending Bonneville Dam in July 2006. Genetic analysis of juvenile *O. mykiss* collected in the upper watershed above Husum Falls found differences from hatchery trout released in the watershed; additional samples are needed, however, to confirm this finding (Allen et al. 2006a).

Additional research by Carmichael (Ruzycki et al. 2003) in the Grande Ronde and by Thrower et al. (2004) in Alaska supports the theory that even though the population is functionally extirpated, there is some potential for re-establishing anadromous steelhead in the White Salmon River watershed. Using resident *O. mykiss* above the former Condit Dam could provide a genetic link to historical anadromous *O. mykiss*.

### *Restoration of Habitat Impacted by Condit Dam and Formerly Occupied by Northwestern Lake*

At the time this document was prepared, PacifiCorp had breached the dam and was in the process of removing the structure. PacifiCorp is currently implementing numerous decommissioning management plans that address protection of aquatic biota, bank stabilization, management of sediment and erosion, revegetation, and several other projects. The condition of the habitat downstream of the dam and that habitat recently occupied by the dam will be unknown for a period of time. A Research, Monitoring and Evaluation (RM&E) entity will complete an assessment of habitat conditions after the dam is fully removed and stabilization efforts are complete. Based on this information, a proposed Washington Gorge Management Unit entity will identify priority restoration actions. These will likely include riparian planting and bank stabilization, as well as other actions to be determined.

### *Habitat Improvement Upstream of Buck Creek in Anticipation of Future Population Growth*

Biologists have completed, or are in the process of completing, assessments of current habitat condition in the upper watershed (particularly Rattlesnake Creek). Based on this information, the Plan identified actions that would improve habitat in the upper watershed in anticipation of eventual anadromous fish population growth and occupation of existing habitat. Actions include placement of LWD, planting and management of riparian areas, improvements in passage, reduction of sediment inputs, reduction of anthropogenic effects on stream flow, and other actions.

**Table ES-2. Recovery Strategies and Actions for White Salmon River Salmon and Steelhead Populations**

| Action Type | Specific Action(s) |
|---|---|
| **Dam Removal and Species Reintroductions** | |
| Complete dam removal | Complete removal of Condit Dam |
| | |
| Restore channel, stabilize banks, replant banks, and restore habitat in inundated area previously occupied by the reservoir, as well as the habitats impacted downstream of the former Condit Dam site | Implement PacifiCorp's Decommissioning Management Plans |
| | Restore channel mainstream above the former Condit Dam |
| | Restore riparian condition |
| | Dredge mouth of White Salmon River if needed |
| Restore populations | Implement reintroduction plan for the White Salmon River salmonids |
| **Post-Dam Removal RM&E** | |
| Baseline habitat data collection | Gather information needed to identify and prioritize habitat actions that will provide the greatest opportunity to contribute to recovery |
| Population monitoring:<br><br>- Monitor population abundance and productivity | Install & maintain large multiplexing PIT-tag detectors in the lower White Salmon mainstem and in Buck & lower Rattlesnake creeks. Report findings |
| <br><br>- Monitor proportion and origin of hatchery salmon and steelhead on the spawning grounds | Implement population monitoring in the White Salmon River & major anadromous-accessible tributaries. |
| | Install two small stationary instream PIT-tag detectors in the lower most portion of Spring Creek |

| Action Type | Specific Action(s) |
|---|---|
| - Assess the resident trout contribution to smolts downstream of the former Condit Dam; assess change in resident population after steelhead re-colonization/reintroduction | Pit-tag 3,000 juvenile salmonid each year upstream and downstream of the former Condit Dam to track individual movement and seasonal growth rates |
| | Conduct adult spawning ground surveys and monitor |
| | Create and maintain fish counts & biological database |
| | Mark adults for mark-recapture population estimates |
| | Derive estimates of salmonid population abundance & complete reporting |
| - Genetic analyses | Compare adult and smolt genetic analyses to ongoing adult salmon escapement estimates of WDFW and smolt outmigration estimates of United States Geographic Survey (USGS) studies in the White Salmon River |
| **Habitat Restoration** | |
| Protect and conserve existing natural ecological processes | Protect existing habitat from future degradation through land use planning |
| | Protect existing habitat from future degradation though land management plans, conservation easements, acquisitions, re-classification of lands as natural areas |
| Restore vegetation along stream sections that exceed state standards for temperature | Identify stream segments that are excessively warm; within those areas, work with willing landowners to implement actions to increase density of riparian vegetation where sparse; implement programs to protect existing riparian vegetation, reduce sediment inputs to streams |
| Restore passage and connectivity to habitats blocked or impaired by artificial barriers | In cooperation with irrigation district and others, remove or replace barriers inhibiting upstream passage including dikes, culverts, and irrigation structures, provide/upgrade screening of irrigation diversions |
| | Indian Creek culvert replacement |
| Reduce nutrient inputs | Reduce runoff of nutrients from septic tanks, dairies, agricultural lands, and other sources |
| Improve LWD abundance and recruitment | In cooperation with landowners plan, design and install stable wood and other large debris in streambeds and develop approaches to ensuring long-term LWD recruitment |
| | In cooperation with landowners develop grazing strategies that promote riparian recovery |
| Invasive species | Eradicate invasive plant species from riparian areas |
| Restore channel | With willing landowners, stabilize stream banks, restore natural channel form, reduce sediment inputs as needed from roads |
| Reduce anthropogenic effects on stream flow | Quantify anthropogenic effects on stream flow and identify priority actions |
| | With willing landowners, implement water conservation measures |
| | Improve irrigation conveyance and efficiency |
| | Employ Best Management Practices (BMP)s with willing landowners |
| | Protect/restore springs with willing landowners |
| | Increase pool habitat |
| | Restore wetlands with willing landowners |
| | Hydrologically disconnect roads from streams |

| Action Type | Specific Action(s) |
|---|---|
| | Control road/stream interactions by reducing erosion potential |
| Public awareness | Public awareness regarding restoration projects and importance of wood in streams and riparian areas |
| **Harvest** | |
| Harvest management | Manage harvest for low impact fisheries and rapid anadromous fish population growth |
| | Adjust tributary harvest regulations in areas where harvest significantly impacts salmon and steelhead population growth |
| **Hatcheries** | |
| Reintroduction: Hatchery production | Rehabilitate White Salmon Ponds and update intake screen |
| **Hydrosystem and Mainstem Predation** | |
| Maintain or improve hydropower operations and facilities at Bonneville Dam to enhance salmon and steelhead survival | Decrease water travel time during smolt outmigration |
| Maintain or improve hydropower operations and facilities at Bonneville Dam to enhance salmon and steelhead survival | Improve operation of adult passage, maintain high standards of adult fish passage at Bonneville Dam |
| Reduce predation on salmonids | Reduce predation by pinnipeds, piscivores, cormorants and Caspian terns |

## Implementation and Cost Estimates

This plan provides specific management strategies and actions needed to address re-establishing viable anadromous salmonid populations in the White Salmon River watershed. These actions represent activities with the greatest potential for protecting and recovering salmon and steelhead, as well as for achieving broad-sense recovery goals. Implementation of recovery actions is not a one time or short-term initiative. The programs and actions will likely need sustaining, evaluating, adjusting, and augmenting over the full recovery period.

NMFS encourages the formation of a planning group for the Washington Gorge Management Unit, a forum or entity that would take responsibility for coordinating implementation of the White Salmon River Watershed Recovery Plan. Implementing the proposed recovery actions for MCR steelhead in the Washington Gorge Management Unit, which includes the White Salmon watershed, would be a primary task for a Washington Gorge Area Regional Board, subject to state, tribal, and local government concurrence and the opportunity for public involvement and comment.

Chapter 7 provides cost estimates developed by the Washington Gorge Implementation Team (WAGIT) for implementing the proposed habitat actions described in Chapter 6 for the White Salmon drainage. The Plan identified numerous RM&E actions. The results of studies will help to identify the priority actions within the watershed. The estimated RM&E actions will cost roughly $1,540,000 over a 5-year period. Implementation of PacifiCorp's decommissioning plans is estimated to cost $0.9 to $1.1 million. Additional actions could cost up to $15,100,000. The total cost over a 5-year period for restoring anadromous populations in the White Salmon River could be as much as $16,781,000. Funding is not yet available to cover $13,200,000 of this cost.

## Monitoring, Research and Adaptive Management Framework

As part of implementing the White Salmon Recovery Plan, the proposed Washington Gorge Management Unit or another entity will design a detailed monitoring and evaluation program, which will be incorporated into an adaptive management framework based on the principles and concepts laid out in the NMFS guidance document, *Adaptive Management for Salmon Recovery: Evaluation Framework and Monitoring Guidance* (available at http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Other-Documents.cfm (accessed April 11, 2012).

The White Salmon monitoring and evaluation program will build on existing programs designed for monitoring tributary habitat in the White Salmon River. Additionally, the program will provide 1) a clear statement of the metrics and indicators by which progress toward achieving goals can be assessed, 2) a plan for tracking such metrics and indicators, 3) a decision framework in which new information from monitoring and evaluation can be used to adjust strategies or actions aimed at achieving the Plan's goals.

# 1 Introduction

The ESA of 1973 requires NOAA's NMFS to develop recovery plans for species listed under the Act. The purpose of recovery plans is to identify actions needed to restore threatened and endangered species to the point where they are again self-sustaining elements of their ecosystems and no longer need the protection of the ESA.

This is a plan for the recovery of White Salmon River populations of fall Chinook salmon and steelhead, and for establishing or re-establishing spring Chinook salmon, coho, and chum salmon populations in the White Salmon River so that they can contribute to the conservation and survival of the threatened LCR Chinook salmon, LCR coho salmon, and CR chum salmon ESUs, and the threatened MCR steelhead DPS.[2]

The White Salmon River drains approximately 386 square miles in southwestern Washington and joins the CR at Underwood, Washington, CR RM 163 (See Figure 1-1).

Salmon and steelhead production in the White Salmon River watershed dropped significantly in the early 1900s after construction of Condit Dam at RM 3.3 on the White Salmon River. Although the original owners constructed Condit Dam with a fish ladder, high flows twice destroyed the ladder, which was not rebuilt after 1919. The dam blocked access to most of the historical range of both spring and fall Chinook salmon, steelhead, and coho salmon populations that once spawned in the watershed. PacifiCorp breached Condit Dam in October 2011 and is currently removing the dam. This recovery plan includes the proposal developed as part of the FERC decommissioning process to re-establish natural production of spring and fall Chinook salmon, coho, chum salmon, and steelhead in the White Salmon watershed, based on natural re-colonization of the habitat above the dam after removal is complete. In addition, the Bonneville Dam reservoir inundated much of the historical spawning habitat of the chum salmon population that historically spawned in the watershed (NMFS 2005). Some salmon and steelhead currently spawn and rear in accessible habitat below Condit Dam.

The watershed's native salmon and steelhead populations are not viable and their respective ESUs/DPSs are now listed for protection under the ESA. The MCR steelhead population in the White Salmon River is considered functionally extirpated (ICTRT 2008) and also the LCR spring Chinook salmon and coho salmon and the CR chum salmon are considered extirpated (Myers et al. 2006).

[2] An 'evolutionarily significant unit' (ESU) of Pacific salmon (Waples 1991) and a 'distinct population segment' (DPS) of steelhead (71 FR 834, January 5, 2006) are considered to be 'species,' as defined in section 3 of the ESA.

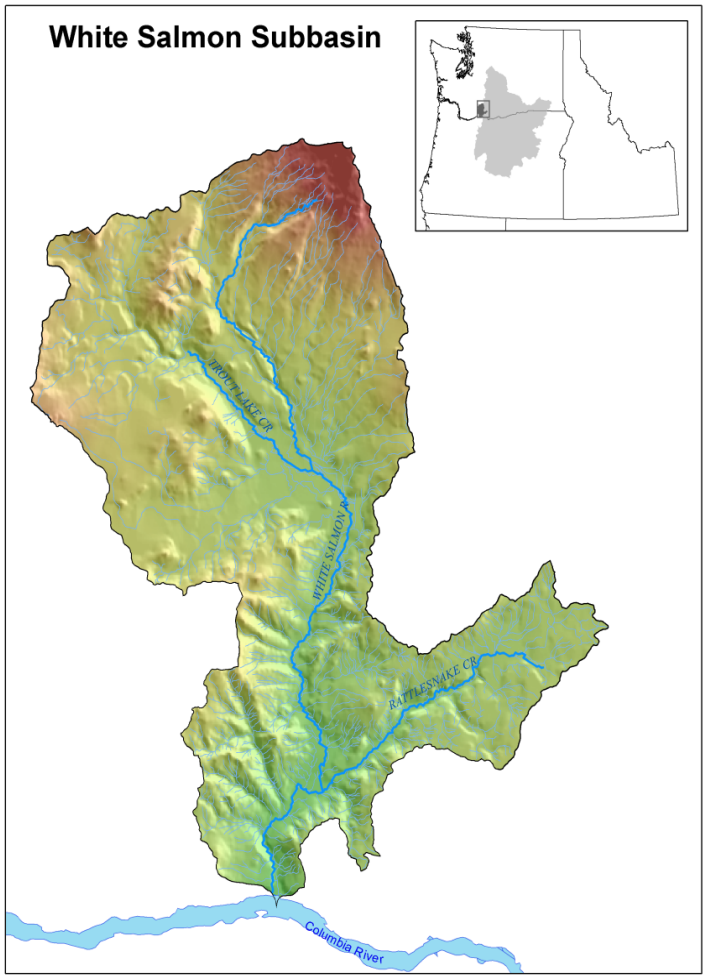


**Figure 1-1. White Salmon watershed in Washington State**

NMFS developed this recovery plan with participation and technical contributions from the YN, WDFW, Klickitat County, Washington State Governor's Salmon Recovery Office, other Federal and state agencies, local governments, and the public. While NMFS is the agency responsible for recovery planning for salmon and steelhead under the ESA, NMFS believes it is critically important to base ESA recovery plans for salmon and steelhead on the many state, regional, tribal, local, and private conservation efforts already underway throughout the region, and has attempted to do so in this plan.

## 1.1 Purpose of Plan

A recovery plan provides a roadmap for restoring a listed species or population to the point where it becomes a viable component of its ecosystem. Recovery plans are not regulatory; they are guidance for recovery efforts. This Plan describes the current status of the White Salmon River salmon and steelhead populations and their habitat in the White Salmon watershed. The Plan also identifies the major limiting factors and threats affecting the populations and proposes strategies and actions designed to aid in population recovery by building on past and current efforts. Finally, the Plan provides an implementation and

adaptive management framework for making needed future adjustments on the road to recovery.

### 1.1.1 ESA Requirements

Section 4(f) of the ESA requires that a recovery plan be developed and implemented for species listed as endangered or threatened under the statute. ESA section 4(a)(1) lists factors for re-classification or delisting, which are to be addressed in recovery plans:

a. Present or threatened destruction, modification, or curtailment of [the species'] habitat or range

b. Over-utilization for commercial, recreational, scientific, or educational purposes

c. Disease or predation

d. Inadequacy of existing regulatory mechanisms

e. Other natural or human made factors affecting its continued existence

ESA section 4(f)(1)(B) directs that recovery plans, to the extent practicable, incorporate:

a. Description of such site-specific management actions as may be necessary to achieve the Plan's goal for the conservation and survival of the species;

b. Objective, measurable criteria which, when met, would result in a determination, in accordance with the provisions of this chapter, that the species be removed from the list;

c. Estimates of the time required and the cost to carry out those measures needed to achieve the Plan's goal and to achieve intermediate steps toward that goal.

Once a species is deemed recovered, and therefore removed from a listed status, section 4(g) of the ESA requires the monitoring of the species for not less than 5 years to ensure that it retains its recovered status.

### 1.1.2 Coordination with Others

This Plan has been developed to achieve consistency with other related planning and management efforts.

#### Federal Treaty and Trust Responsibilities

Northwest Indian Tribes have legally enforceable rights reserving to them a share of the salmon harvest. In the Treaties of 1855 between the U.S. Government and the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes and Bands of the Yakama Indian Nation, the Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce Tribe, the tribes, in exchange for the preponderance of their lands, reserved the rights to fish within their reservations and "at all other usual and accustomed places." The usual and accustomed places are understood to include the millions of acres of aboriginal land ceded to the United States in the 1855 treaties, which extends to the upper Columbia and Snake River Basins, and includes most of the geographic range of the middle Columbia

steelhead DPS. A complex history of treaties, executive orders, legislation, and court decisions have culminated in the recognition of tribes as co-managers who share management responsibilities and rights for fisheries in the Columbia Basin.

Achieving the basic purpose of the ESA (to bring the species to the point that it no longer needs the protection of the Act) may not by itself fully meet these rights and expectations, although it will lead to major improvements in the current situation. Ensuring a sufficient abundance of salmon to sustain harvest is an important element in fulfilling trust and treaty rights as well as garnering public support for these plans. ESA and tribal trust responsibilities complement one another. Both depend on a steady upward trend toward ESA recovery and delisting in the near term, while making aquatic habitat, harvest, and land management improvements for the long-term.

It is appropriate for recovery plans to take these considerations into account and plan for a recovery strategy that includes harvest. In some cases, increases in the naturally spawning populations may be sufficient to support harvest. In others, the recovery strategy may include appropriate use of hatcheries to support a portion of the harvest. So long as the overall plan is likely to achieve the recovery of the listed ESU/DPS, it will be acceptable as a recovery plan.

The NMFS Regional Administrator, in testimony before the U.S. Senate Indian Affairs Committee (June 2003), emphasized the importance of this co-manager relationship: "We have repeatedly stressed to the region's leaders, tribal and non-tribal, the importance of our co-management and trust relationship to the tribes. NMFS enjoys a positive working relationship with our Pacific Northwest tribal partners. We view that relationship as crucial to the region's future success in recovery of listed salmon."

Treaty Indian fishing rights in the CR Basin are under the continuing jurisdiction of the U.S. District Court for the District of Oregon in the case of *U.S. v. Oregon*, No. 68-513 (filed in 1968). The parties to *U.S. v. Oregon* are the United States acting through the Department of Interior (USFWS and Bureau of Indian Affairs (BIA)) and Department of Commerce (NMFS), the Warm Springs, Umatilla, Nez Perce, Yakama, and Shoshone-Bannock Tribes, and the states of Oregon, Washington, and Idaho. In *U.S. v. Oregon*, the Court affirmed that the treaties reserved for the tribes 50 percent of the harvestable surplus of fish destined to pass through their usual and accustomed fishing areas.

The White Salmon watershed contains lands ceded to the United States by the YN in the Treaty of June 9, 1855. Within this area, the Tribe reserves the right "to hunt and fish at all usual and accustomed places." An in-lieu fishing site is located in the White Salmon River upstream of the bridge at the mouth. This location allows tribal fishers to launch boats in an enclosed area and move out into the CR to their usual and accustomed fishing sites.

Several historical seasonal encampments and fishing areas used by local Indian bands were located on the White Salmon and its tributaries. Historically, before European settlement of the area, significant fisheries and winter village sites were located at the mouth of the White Salmon, at Husum Falls, RM 7.6 and at the falls at BZ Corner, RM 12.4. Another important winter village was located at Trout Creek (Lane and Lane Associates 1981). The Yakama people occupied the entire Rattlesnake Creek drainage. Villages were located near the confluence of the White Salmon River and Rattlesnake Creek, and another approximately

four miles up the creek. The upper White Salmon watershed also contains current and historical huckleberry fields traditionally used by the YN. Archaeological sites throughout the area testify to the importance of the White Salmon watershed as a seasonal and perennial area of aboriginal use. Present day tribal groups whose treaty reserved fisheries were affected by Condit Dam are the Confederated Tribes and Bands of the Yakama Indian Nation, Confederated Tribes of the Warm Springs Reservation of Oregon, Confederated Tribes of the Umatilla Reservation of Oregon, and the Nez Perce Tribe of Idaho (Lane and Lane Associates 1981).

### Other Federal, State and Local Responsibilities

To ensure consistency in goals, strategies, and actions and to eliminate duplication of effort, planners and program administrators have endeavored to achieve consistency between ESA recovery plans, the Northwest Power and Conservation Council (NPCC) fish and wildlife program, the State of Washington watershed management and salmon recovery programs, and local planning and regulatory efforts.

This Recovery Plan builds upon the White Salmon Subbasin Plan (NPCC 2004), which was developed for the NPCC by the YN, WDFW, and other Federal, state, and local entities. The Plan contains an assessment and inventory of fish and wildlife resources in the watershed, as well as a management plan identifying locally informed fish and wildlife protection and restoration priorities. The NPCC adopted the White Salmon Subbasin Plan into its Fish and Wildlife program. Additional scientific data are drawn from other more recent sources, including technical products developed by TRTs appointed by NMFS for the Interior Columbia and Willamette/lower Columbia Willamette lower Columbia recovery domains and studies completed by the YN Fisheries, the U.S. Geological Survey (USGS), USFWS, and the Underwood Conservation District (UCD).

This Plan is the product of a process initiated by NMFS, involving technical input from the YN, WDFW, Klickitat County, the Washington State Governor's Salmon Recovery Office, LCFRB, other Federal agencies, state agencies, local governments, and the public. The Plan's recovery strategy for White Salmon River salmon and steelhead includes recommendations by these parties.

## 1.2 Context of Plan Development

Currently, there are 18 ESA-listed ESUs/DPSs of Pacific salmon and steelhead in the Pacific Northwest. For the purpose of recovery planning for these species, NMFS Northwest Region designated five geographically based "recovery domains": Interior Columbia; W/LC; Puget Sound and Washington Coast; the Oregon Coast; and the Southern Oregon/Northern California Coast.

The White Salmon watershed is in an area of overlap between the Interior Columbia and W/LC recovery domains. Columbia River Chinook salmon, coho, and chum salmon are included in the W/LC domain. A run of fall Chinook salmon continues to exist in the watershed. Chum, coho and spring Chinook salmon are considered extinct, extirpated, or functionally extirpated (Myers et al. 2006).

The range of the middle Columbia River Steelhead DPS includes the White Salmon River watershed. The White Salmon River steelhead population is considered functionally extirpated. The entire recovery plan for the White Salmon River population of Middle Columbia River steelhead was not included in the *Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan*. The Middle Columbia River plan explains that while the White Salmon watershed, which historically supported a population of Middle Columbia River steelhead, is part of the Washington Gorge management unit, the recovery plan for that population was being finalized as part of the *Lower Columbia ESA Recovery Plan*. The reason for including the White Salmon River population of Middle Columbia steelhead in the Lower Columbia ESA Recovery Plan was because the White Salmon River also includes single populations of three listed ESUs of salmon (Lower Columbia River Chinook and coho salmon and Columbia River chum). The need for an ecosystem approach warranted addressing all the listed salmonids that spawn in the White Salmon watershed in one plan. However, the delisting criteria, actions, and costs for the White Salmon River steelhead population are included in the Middle Columbia DPS plan in order to have all the information on the Middle Columbia steelhead DPS in one place. The Middle Columbia River steelhead DPS recovery plan will be updated to include the White Salmon Management Unit plan as an appendix. However, inclusion of the White Salmon Management Unit plan does not alter the recovery criteria articulated for the White Salmon River steelhead population in the Middle Columbia River steelhead DPS recovery plan.

**Technical Recovery Teams (TRT)**

For each domain, NMFS appointed a team of scientists, nominated for their geographic and species expertise, to provide a solid scientific foundation for recovery plans. The charge of each TRT was to define ESU/DPS structures, develop recommendations on biological viability criteria for each ESU or DPS and its component populations, provide scientific support to local and regional recovery planning efforts, and provide scientific evaluations of proposed recovery plans. Both the W/LC TRT and the ICTRT did work relevant to the White Salmon populations. Each TRT included scientists from NMFS, states, tribal entities, academic institutions, and other Federal agencies.

All the TRTs used the same biological principles for developing their recommendations for ESU/DPS and population level viability criteria-criteria to be used, along with criteria based on mitigation of the factors for decline, to determine whether a species has recovered sufficiently to be downlisted or delisted. These principles are described in a NMFS technical memorandum, *Viable Salmon Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). VSPs are defined in terms of four parameters: abundance, productivity or growth rate, spatial structure, and diversity. A viable ESU/DPS is naturally self-sustaining, with a high probability of persistence over a 100-year time period. Each TRT made recommendations using the VSP framework and based on data availability, the unique biological characteristics of the ESUs/DPSs and habitats in the domain, and the members' collective experience and expertise. Although NMFS has encouraged the TRTs to develop regionally specific approaches for evaluating viability and identifying factors limiting recovery, all the TRTs are working from a common scientific foundation.

### 1.2.1 Planning Forum

In each of the W/LC and Interior Columbia recovery domains, NMFS has worked with state, tribal, local, and other Federal entities to develop planning forums that build to the extent possible on ongoing, locally led recovery efforts. NMFS defined "Management Units" based on jurisdictional boundaries as well as areas where local planning efforts were underway. The W/LC Domain has four management units: 1) Oregon, 2) Washington, 3) White Salmon and 4) Upper Willamette. The middle Columbia, a sub-domain of the Interior Columbia, also has four management units: 1) Oregon; 2) Washington Gorge, which, in turn, is subdivided into three planning areas; White Salmon, Klickitat, and Rock Creek; 3) Yakima Basin; 4) Southeast Washington.

NMFS works with recovery planning forums developed by the State. In Washington State these forums typically include representatives from state, tribal, local governments, and other stakeholders. The appropriate jurisdictions have not yet established a planning forum for the Washington Gorge Management Unit. Therefore, NMFS has worked independently with the YN, Klickitat County, WDFW, and local entities to develop the recovery plan for White Salmon River salmon and steelhead populations. NMFS encourages creation of a local planning forum that could provide guidance for further development and implementation of recovery plans for the Washington Gorge Management Unit.

## 1.3 How NMFS Intends to Use the Plan

Although recovery plans are not regulatory and their implementation is voluntary, they are important tools that help to do the following:

- Provide context for regulatory decisions
- Guide decision making by Federal, state, tribal, and local jurisdictions
- Provide criteria for status reporting and delisting decisions
- Organize, prioritize, and sequence recovery actions
- Organize research, monitoring, and evaluation efforts

NMFS will encourage Federal agencies and non-Federal jurisdictions to take recovery plans under serious consideration as they make the following sorts of decisions and allocate their resources:

- Actions carried out to meet Federal ESA section 7(a)(1) obligations
- Actions that are subject to ESA sections 4d, 7(a)(2), or 10
- Hatchery and Genetic Management Plans and permit requests
- Harvest plans and permits
- Selection and prioritization of basin and watershed planning actions
- Development of research, monitoring, and evaluation programs
- Revision of land use and resource management plans

- Other natural resource decisions at the state, tribal, and local levels

NMFS will emphasize recovery plans in ESA section 7 (a)(2) consultations, section 10 permits, and application of the section 4(d) rule by considering:

- Delisting criteria that address both viability and threats
- Description of limiting factors and threats (factors for decline)
- Description of a recovery program (site specific management actions necessary to achieve recovery of the species)
- Estimates of the time and cost to carry out measures to achieve the Plans' goals

In implementing these programs, recovery plans will be used as a reference and a source of context, expectations, and goals. Under section 7 of the ESA, NMFS staff will encourage the Federal "action agencies" to describe in their biological assessments how their proposed actions will affect specific populations, the limiting factors identified in the recovery plans, and any mitigating measures and voluntary recovery activities in the action area.

# 2 Biological Background

This chapter describes population and habitat characteristics for the White Salmon River salmon and steelhead populations. The chapter also discusses hatchery production and releases and harvest management in the White Salmon River watershed.

## 2.1 Populations and Major Population Groups

***Lower Columbia River Chinook salmon***

White Salmon River fall and spring Chinook salmon are included in the LCR Chinook salmon (*Oncorhynchus tshawytscha*) ESU, which NMFS listed as threatened on March 24, 1999, and reaffirmed on June 28, 2005. The ESU includes all naturally spawned populations of Chinook salmon in the CR and its tributaries from its mouth at the Pacific Ocean upstream to a transitional point east of Hood River in Oregon and the White Salmon River in Washington. The historical site of Celilo Falls on the CR is considered the transitional point for this ESU, since it may have been a migration barrier to Chinook salmon at certain times of year (Myers et al. 1998). The ESU exhibits three major life history types: fall-run (tules), late fall-run (brights), and spring-run. The White Salmon River historically supported two of these life history strategies: fall-run Chinook salmon tules (Figure 2-1), and spring-run Chinook salmon (Figure 2-2).

There is no direct documentation of a historical (pre-Condit Dam) population of naturally spawning spring Chinook salmon (Myers et al. 2006). Fulton (1968) speculated that tribal members historically caught Chinook salmon upstream of Husum Falls, which were likely spring Chinook salmon, citing Bryant (1949) and USFWS (1951). These reports, however, did not indicate direct observations. Evermann and Meek (1898) surveyed the White Salmon River in August and September. No Chinook salmon were observed in August, possibly due to conditions not being conducive to observation due to flooding from the CR and to investigating only the lower mile of the river. Additionally, LeMier and Smith (1955) interviewed a long time resident who was unable to confirm the presence of spring Chinook salmon in the watershed.

Even though documentation of direct observations of spring Chinook salmon by 20$^{th}$-centery residents, Myers et al. 2006 determined, based on the historically available habitat, that spring Chinook salmon were historically present in the basin. The observation of a spring Chinook salmon redd above Husum Falls on September 20, 2012, further supports the historical presence of spring Chinook salmon in the basin (personal communication R. Engle, USFWS, 2012). The determination that the redd observed belonged to spring Chinook salmon was based on the timing of the redd (prior to tule fall Chinook salmon spawning), the size (too large for resident trout), and its location above Husum Falls (no fall Chinook salmon have been observed above Husum Falls).

LeMier and Smith (1955) evaluated the capacity of the White Salmon River to support salmon if passage was re-established. Under conditions existing in 1955, they estimated the river could support 732 spring Chinook salmon and 452 fall Chinook salmon, but noted that conditions in the White Salmon River were degraded substantially in 1955 relative to historical levels. Ecosystem Diagnosis and Treatment (EDT) modeling indicated the historic

potential abundance of fall Chinook salmon was roughly 775 adults. This figure is less than the estimated current potential without harvest, which suggests some error in the model assumptions or the reporting of results (Allen and Connolly 2005). The EDT modeling indicated the historic potential abundance of spring Chinook salmon was roughly 825 adults.

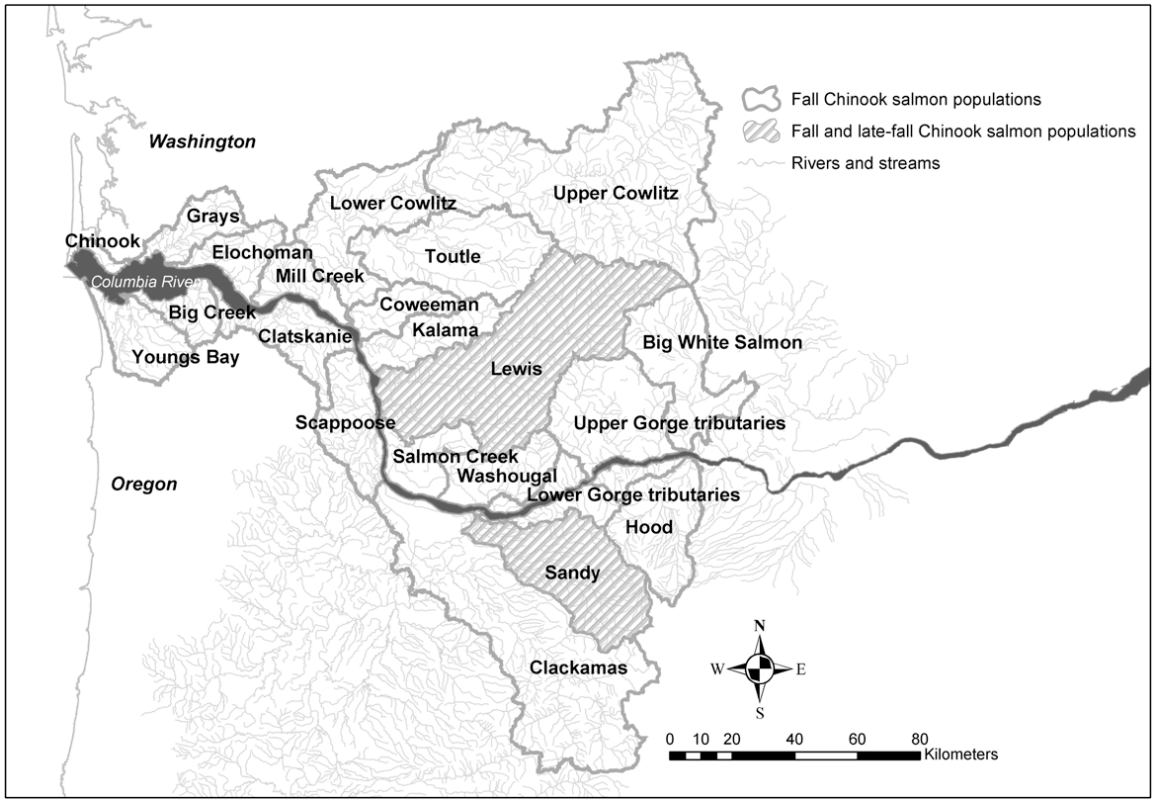


**Figure 2-1. Historical fall and late fall demographically independent populations in the lower Columbia River Chinook salmon ESU (Myers et al. 2006)**

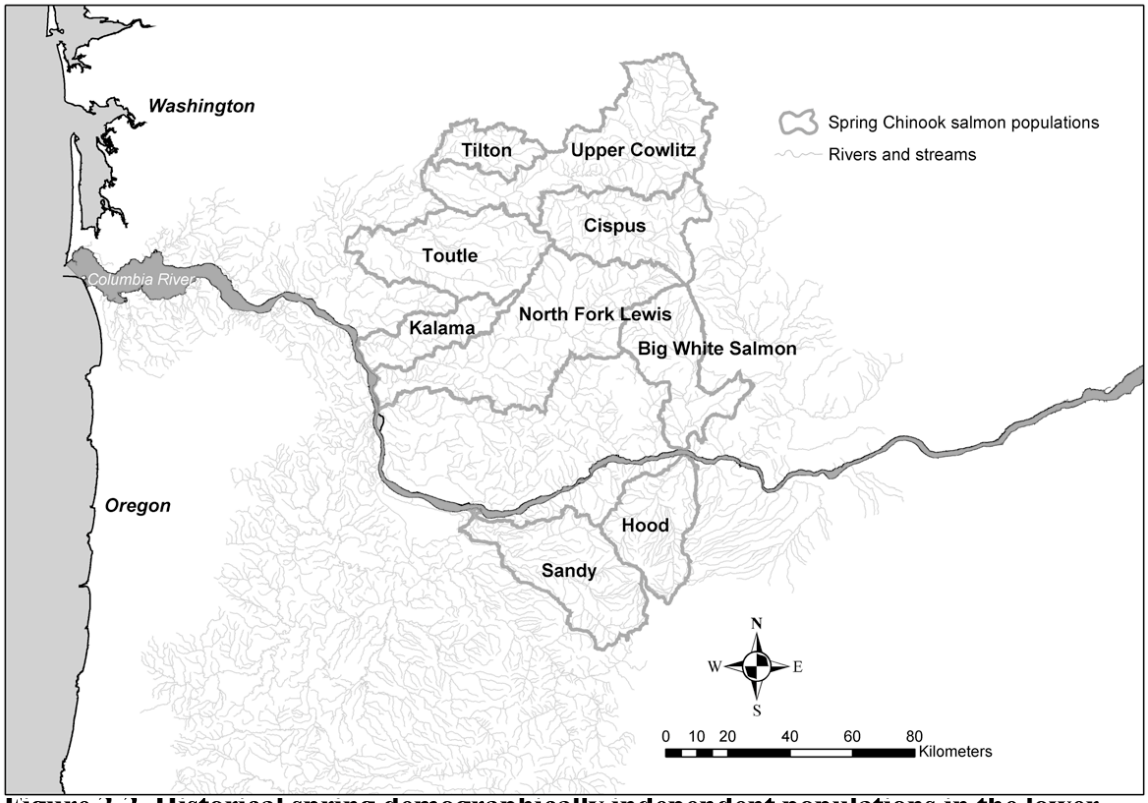


**Figure 2-2. Historical spring demographically independent populations in the lower Columbia River Chinook salmon ESU (Myers et al. 2006)**

### *Lower Columbia River coho salmon*

White Salmon River coho salmon are part of the LCR coho salmon (*Oncorhynchus kisutch*) ESU, which NMFS listed as threatened on June 28, 2005. The ESU includes all naturally spawned coho salmon populations in the CR and its tributaries from the mouth of the CR to a transitional point east of the Hood River in Oregon and the White Salmon River in Washington (Figure 2-3). At the time of listing, biologists identified only two naturally spawning populations: the Sandy River and the Clackamas River populations in Oregon.

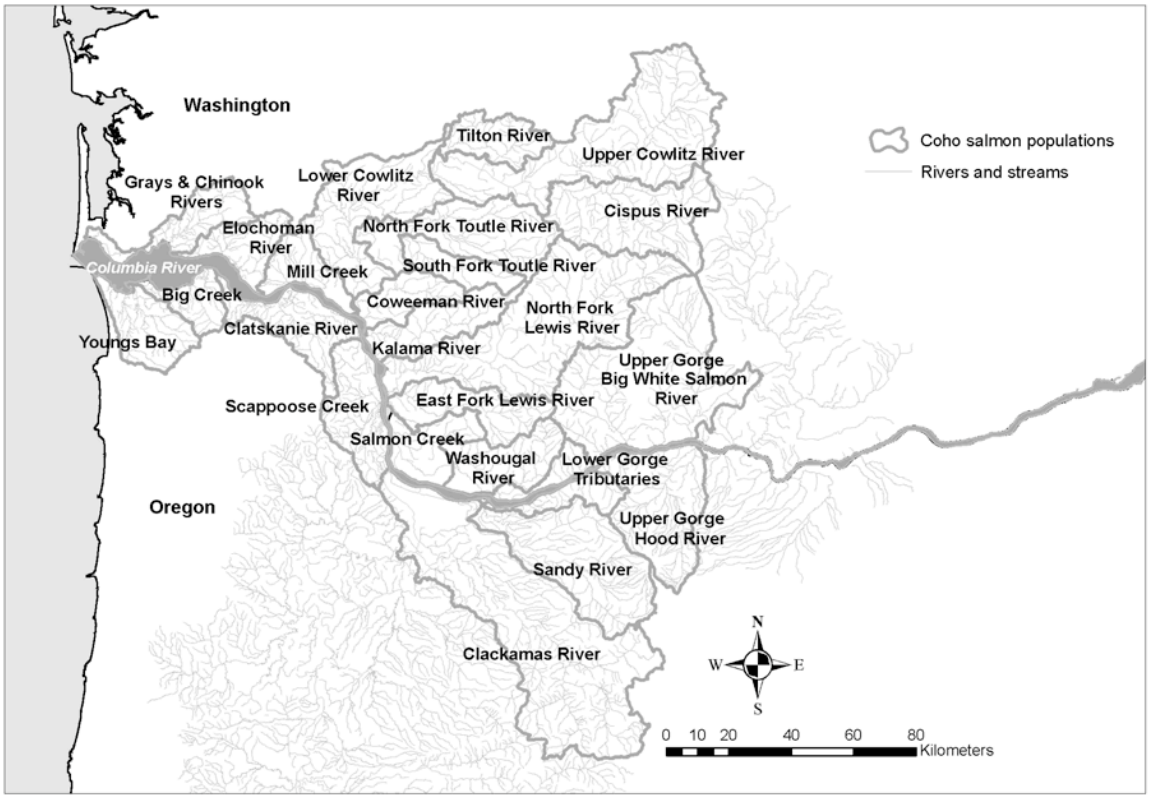


**Figure 2-3. Historical demographically independent populations in the lower Columbia River Coho salmon ESU (Myers et al. 2006)**

***Columbia River chum salmon*** **-** White Salmon River chum salmon were part of the upper Gorge Tributaries population of CR chum salmon *(Oncorhynchus keta*) ESU, which NMFS listed as threatened on March 25, 1999, and reaffirmed on June 28, 2005. The ESU includes all naturally spawning populations in the CR and its tributaries in Washington and Oregon (Figure 2-4).

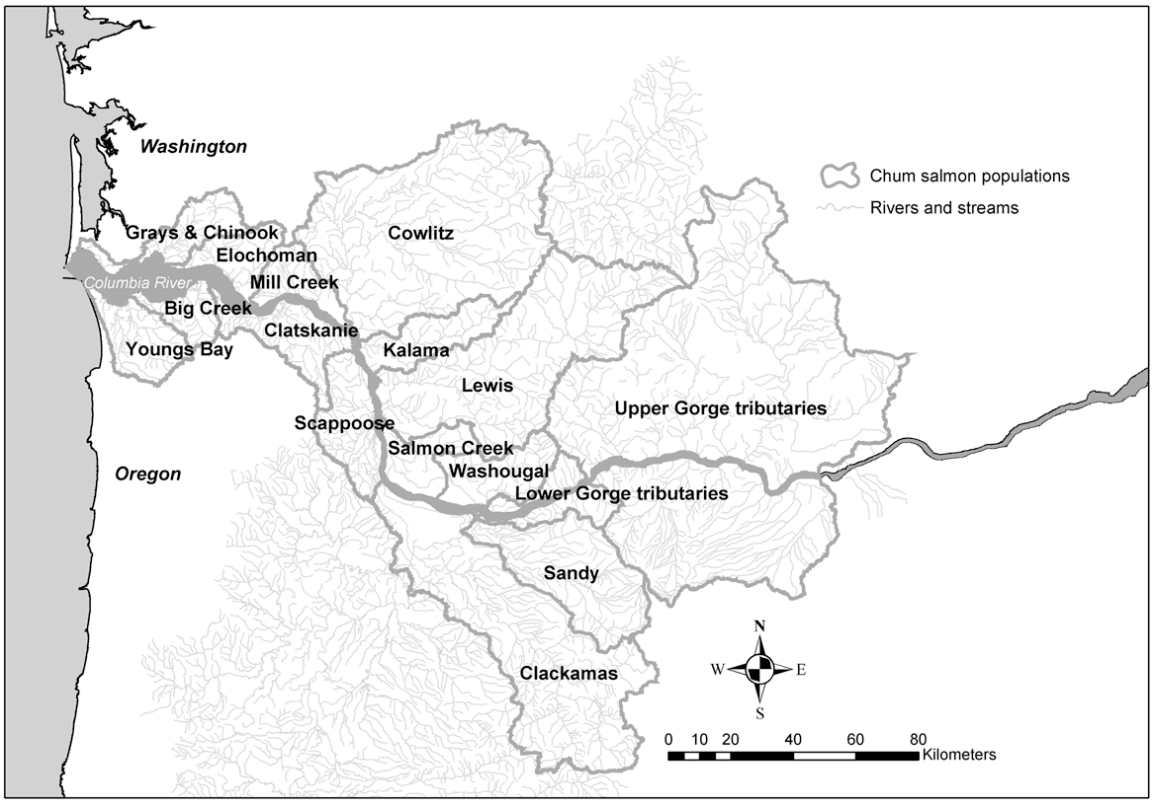


**Figure 2-4. Historical demographically independent populations in the Columbia River chum salmon ESU (Meyers et al. 2006)**

### *Middle Columbia River Steelhead*

White Salmon River steelhead are part of the MCR Steelhead (*Oncorhynchus mykiss*) DPS, which NMFS listed as threatened on January 5, 2006. This DPS includes all naturally produced steelhead in the CR Basin upstream of the Wind River in Washington and the Hood River in Oregon (exclusive) to the Yakima River in Washington. Excluded are steelhead from the Snake River Basin (Busby et al. 1996). The MCR Steelhead DPS includes the only populations of inland winter steelhead in the United States (in the Klickitat and White Salmon rivers, Washington, and in Fifteenmile Creek, Oregon). The ICTRT identified 20 populations within the DPS (16 summer-run and 4 winter-run). In addition the ICTRT identified the historical populations that have been extirpated in Willow Creek due to dam construction in the Deschutes River Basin (ICTRT 2004). Figure 2-5 shows populations within the DPS. The White Salmon population was initially considered to be one of the extirpated populations, (however, later analysis defined the population as being functionally extirpated (ICTRT 2007b).

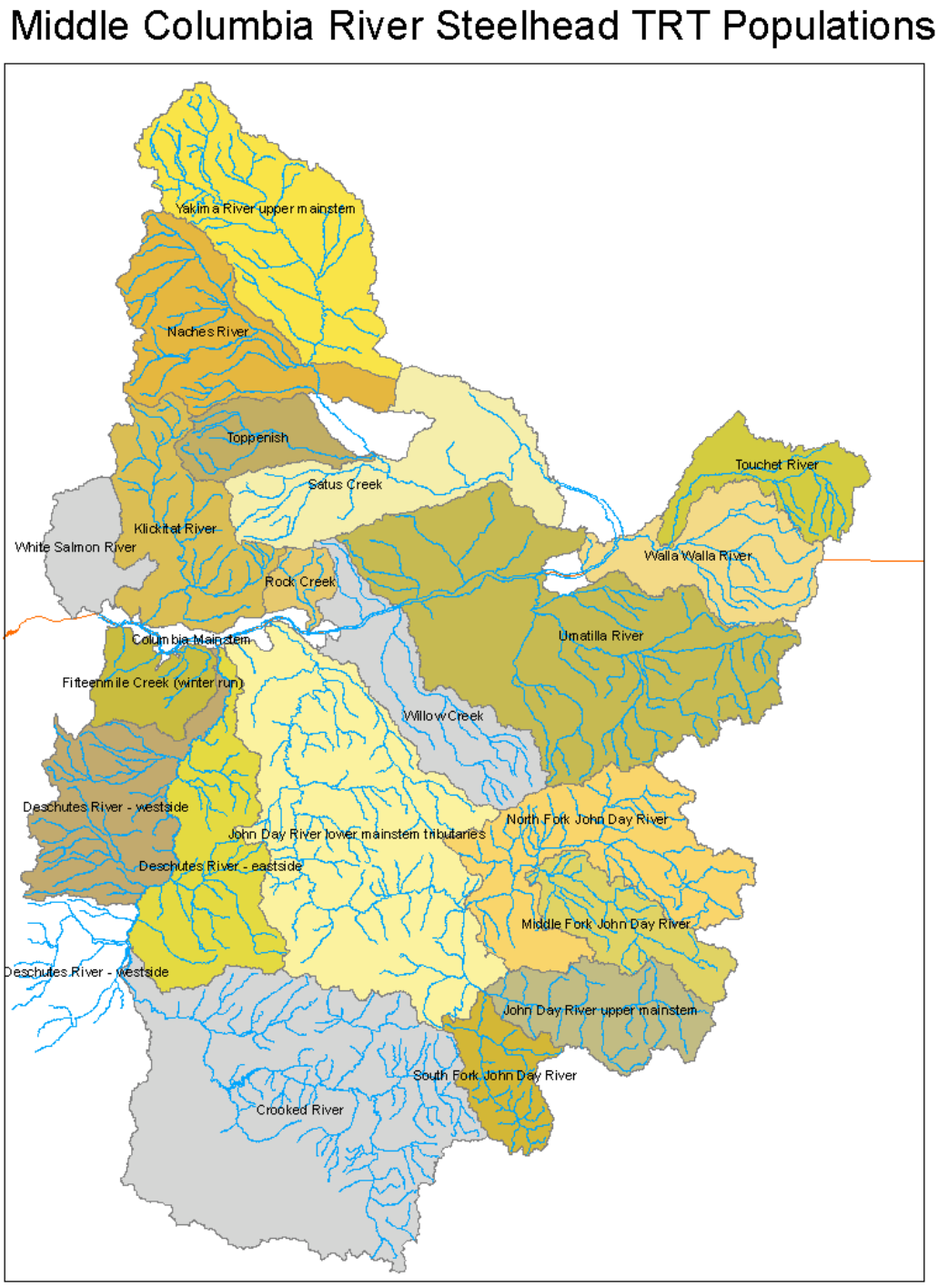


**Figure 2-5. Historical summer and winter steelhead populations in the middle Columbia River DPS (ICTRT 2004; ICTRT 2007b). Note populations in gray are extirpated or functionally extirpated**

## 2.2 Physical Setting

The White Salmon River watershed drains approximately 386 square miles in south central Washington. The river begins along the south slope of Mt. Adams and flows south 45 miles to enter the CR at Underwood, Washington at CR RM 168.3. Elevation in the watershed ranges from 12,307 feet on Mt. Adams to 72 feet at the river's mouth.

The White Salmon River watershed lies primarily within Klickitat County, however, the lower river below the top end of the former Northwestern Lake is shared with Skamania County, and the headwaters of the watershed also extend into Skamania and Yakima counties. These counties have a combined human population of 395,000 with less than 9,000 people living in the White Salmon watershed, http://www.ofm.wa.gov/pop/smallarea/default.asp (accessed April 11, 2012). The watershed falls within Washington State's WRIA 29b. Half of the watershed lies within the Gifford Pinchot National Forest and supports timber production and recreational uses.

Several reaches of the White Salmon River have received special designations because of their scenic value. The nine-mile reach from the confluence of Gilmer Creek near BZ Corner to Buck Creek was designated a Federal Wild and Scenic River in 1986. The upper White Salmon from the headwaters to the boundary of the Gifford Pinchot National Forest, and Cascade Creek from its headwaters to its confluence with the White Salmon River was designated as a National Wild and Scenic River in 2005. The reach from the former location of Condit Dam, RM 3.3, to the mouth is within the boundaries of the CR Gorge National Scenic Area. Recovery actions within these designated scenic areas should be coordinated with the U.S. Forest Service (USFS) to ensure the scenic values are maintained.

## 2.3 Ecosystem Conditions

The watershed lies within a transitional ecosystem area. Western portions of the watershed receive moderate to heavy precipitation. Eastern portions of the watershed are substantially more arid. Vegetation reflects this transitional location, with mixed forests covering about 95 percent of the watershed and grasslands and shrub steppe dominating remaining areas (Haring 2003). Trout Lake Valley, the major watershed valley, is surrounded by hills to the west and rolling plateaus to the east.

The White Salmon River and tributaries carve a watershed that is often rugged and steep, reflecting its past volcanic activity (Figure 2-6). From its headwaters, the White Salmon cuts sharply through mountains with precipitous cliffs and deeply incised canyons, dropping more than 5,000 feet in elevation before it reaches Trout Lake near RM 26, with a gradient change of 200 feet per mile (4 percent) between RM 35 and RM 30. The White Salmon loses another 1,800 feet in elevation from Trout Lake to the Columbia River. Gradient drops an average of 100 feet per mile (2 percent) from RM 17 to RM 12 as the river flows through a steep gorge with several falls. Tributaries between RM 7.6 and 16.3 are inaccessible to fish because of high falls at their mouths (NPCC 2004; WDFW and YN 1990).

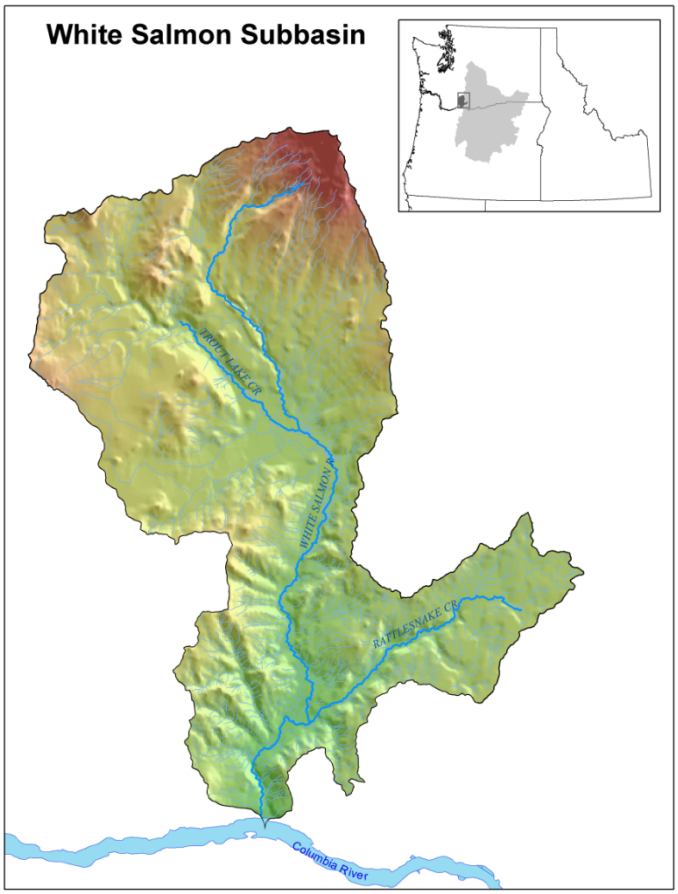


**Figure 2-6. White Salmon River watershed topography and hydrology (NPCC 2004)**

### 2.3.1 Hydrology

The White Salmon River mainstem naturally has a relatively constant natural flow pattern because of glacial melt, large water recharge, and storage capacity. Today this constant flow regime continues throughout the mainstem. Recharged water is released mostly in the middle portion of the mainstem canyon between the Trout Lake Valley and Husum Falls. Peak flows in the mainstem reflect snowmelt runoff, increasing from an average daily flow of 644 cfs during fall months to flows of 1,538 cfs in the spring (Haring 2003).

Operations at Condit Dam altered flows in the White Salmon River below the dam, causing flows to drop to as low as 15 cfs in the 1.1-mile bypass reach compared to natural flows of about 700 cfs. Power peaking at the dam affected the river system by causing diel flow variations and by impairing watershed processes, such as the transportation of spawning gravels and LWD to areas downstream of the project (NPCC 2004). The dam was breached in October, 2011 and flows will return to the natural condition as the final stages of dam removal are completed.

Tributary reaches of the White Salmon generally have more volatile flows than the mainstem, dropping to low levels in the summer and peaking in the winter. Some tributaries flow only during high flow events and are dry the remainder of the year (NPCC 2004). Some

of these tributaries may also be affected by exempted wells that can reduce recharge rates and flows.

### 2.3.2 Migration Barriers

Condit Dam, constructed at RM 3.3, was completed in 1913 and blocked upstream migration of anadromous fish since that time, as well as causing high mortality for outmigrating juveniles. The dam was breeched in 2011 and completely removed by October 2012. Anadromous salmonids now have complete access to habitat upstream of RM 3.3.

Prior to construction of the dam, the upstream limit of all anadromous fish migration in the White Salmon River, except for possibly Pacific lamprey, was the upper falls at Big Brother Falls, RM 16.2, which is approximately 29 feet high. Historic reports of steelhead occurring above Big Brother Falls (Lane and Lane Associates1981) were apparently large resident rainbow trout (*O. mykiss*) confused as being steelhead (Chapman et al. 1990; Bair et al. 2002). BZ Falls at RM 12.4, about 15 to 17 feet high, is likely to be the upstream limit for all salmonids, except for steelhead. Steelhead will likely be able to pass BZ Falls, but the upstream extent of the potential steelhead habitat will not extend beyond Big Brother Falls. Downstream of BZ Falls, Husum Falls, RM 7.6, was probably the historical barrier to fall-run Chinook salmon, sea-run coastal cutthroat trout, and perhaps coho salmon. Blasting shortly after the construction of Condit Dam reduced the height of the falls (Lane and Lane Associates 1981). In its current configuration, Husum Falls is not a barrier to the passage of adult resident or anadromous salmonids, except at low fall flows, and will likely be a barrier to the upstream passage of juvenile salmonids and adult chum salmon. Numerous barrier falls 4 feet in height or greater on the river between Husum and Big Brother Falls will be partial or complete barriers to the upstream migration of juvenile salmonids (LeMier and Smith 1955).

Barriers also restrict salmon and steelhead production in several White Salmon tributaries. With the exception of steelhead, and possibly coho salmon under ideal flow conditions, the falls at RM 1.5 on Rattlesnake Creek and RM 0.8 on Mill Creek will be barriers to upstream migration for all salmonids. A 4-foot high diversion dam at RM 1.9 on Buck Creek will be a barrier to the upstream migration of salmonids < 9 inches in length (Bair et al. 2002). A waterfall at RM 3.2 on Buck Creek and the hydro project dam at RM 0.7 on Spring Creek will be complete barriers to upstream salmonid migration, as is a double-fall (72-82 feet) at RM 10.6 on Rattlesnake Creek (Allen et al. 2003).

### 2.3.3 Riparian Function and Conditions

In comparison to other CR subbasins, the White Salmon watershed is lightly to moderately developed. However, historical logging practices, including mainstem splash damming, and associated road building and inappropriate riparian grazing have likely resulted in modification of flows, increased sedimentation, reduced riparian vegetation, loss of LWD, and increased summer temperature in some areas (NPCC 2004).

Until 1974, timber harvest typically extended to the edge of the stream/river. These practices were restricted in 1974 and have been further restricted in subsequent modifications of the Washington State Forest Practices Rules

http://www.dnr.wa.gov/Publications/fp_rules_history.pdf (accessed April 11, 2012). Additionally, the USFS prohibits harvest in riparian areas along fish bearing streams www.reo.gov/general/aboutNWFP.htm (accessed July 13, 2010).

Grazing has occurred since the late 1800s in the Rattlesnake Creek watershed and Trout Lake Valley, reducing native vegetation. Large historic marsh areas in the upper Rattlesnake Creek watershed were drained in the early 1900s to improve grazing conditions (Haring 2003). Today timber practices have improved, grazing is better managed, and wetland draining has stopped. Nevertheless, many impacts of past land use actions remain in the watershed (Haring 2003). Residential development is occurring with increasing frequency in the lower watershed and along State Route 141; however, construction within the riparian area is largely prohibited.

Some habitat areas in the White Salmon River and tributaries remain healthy, but land use activities affect many areas. EDT modeling results suggest that mainstem habitat is in better shape than tributary habitat, with maximum temperatures, minimum temperatures, and dissolved oxygen remaining at optimum levels (Allen and Connolly 2005). The EDT modeling was completed prior to removal of the dam in 2011, and the model results do not reflect current conditions in the former lakebed or downstream of the dam. New data collected since the modeling was completed indicate that temperature meets Washington state water quality standards throughout the anticipated anadromous range with the exception of Rattlesnake Creek, which occasionally approaches lethal temperatures in some locations in some years (White and Plumb 2004; White and Plumb 2005; White and Cochrane 2005; Connolly 2003; Morris 2005). Habitat surveys completed in the watershed indicate that large wood and pools are low in frequency throughout the Rattlesnake watershed and many of the existing pools are of poor quality (shallow with little cover) (Allen and Connolly 2006a). Unscreened diversions in some locations may potentially affect juvenile survival. Nutrient levels in many portions of the watershed are quite high, up to two times the EPA recommended standard (White and Plumb 2004, 2005; White and Cochrane 2005, Environmental Protection Agency (EPA) 2000).

## 2.4 Life History Characteristics

### 2.4.1 White Salmon River Chinook salmon

This section describes fall and spring Chinook salmon populations in the White Salmon River watershed.

#### Abundance and Productivity

The W/LC TRT recognizes two historical independent Chinook salmon populations in the watershed: White Salmon River fall-run Chinook salmon and White Salmon River spring-run Chinook salmon (Myers et al. 2003; Myers et al. 2006). These historical Chinook salmon populations are considered to be part of the Gorge stratum (or Major Population Group (MPG)) of the lower Columbia Chinook salmon ESU (Myers et al. 2006). These populations are described below.

### *Fall Chinook salmon*

Biologists consider tule fall Chinook salmon native to the system, although the historical size of the fall-run to the White Salmon River is unknown. Past hatchery records indicate that fall-run Chinook salmon in the LWS and White Salmon rivers began spawning in early September, with peak egg takes in the later part of the month (September 21, 1901); 12,840,700 eggs were collected in 1901 (Myers et al. 2003; Myers et al. 2006; Bowers, 1902).

The current stock origin for the naturally spawning tule fall Chinook salmon is considered mixed (NOAA 2005). Hatchery tule fall Chinook salmon were last released in the White Salmon River in the 1980s, but strays are commonly recovered in the river (WDFW 2003). The Spring Creek NFH is located on the CR approximately one mile west of the mouth of the White Salmon River.

Most of the fish spawning naturally in the White Salmon River were assumed to be hatchery-origin tule fall Chinook salmon based on CWT recoveries. The USFWS (2004) estimated natural-origin fall Chinook salmon escapement in the White Salmon River by subtracting the hatchery component calculated by expanding the number of CWT recovered during carcass surveys by the Spring Creek Hatchery brood year tag rate from the total tule escapement (Figure 2-7). Spring Creek NFH began marking all of its hatchery production in 2004 and as a result, recent spawning ground surveys have shown that the majority of the tule fall Chinook salmon returning to the White Salmon River are of natural origin (Roler 2011). The total number of fall Chinook salmon spawners (natural-origin and hatchery) has averaged 2,750 from 1998-2007, even with low returns in the early 2000s (USFWS 2004; Roler 2009). The recent 10-year average (2002-2011) for escapement of natural spawning tule fall Chinook salmon in the White Salmon River has increased to 3,127 adults (Roller 2012). Smith et al. (2007) determined that Spring Creek NFH tule fall Chinook salmon and natural-origin fall tule fall Chinook salmon in the White Salmon were genetically similar and were distinct from other tule fall Chinook salmon populations in the LCR ESU. Natural spawning tule fall Chinook salmon were also found to have not interbred with URB fall Chinook salmon that also spawn in the White Salmon River (Smith and Engle 2011).

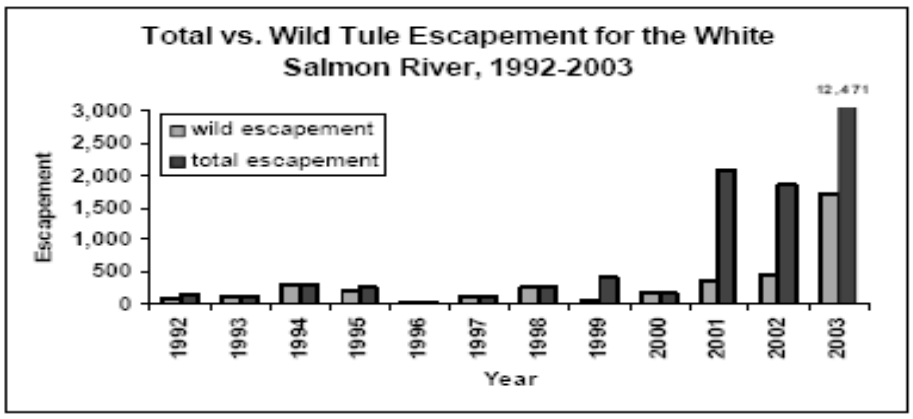


**Figure 2-7. Wild and total tule fall Chinook salmon escapement for the White Salmon River from 1992-2003 (USFWS 2004)**

### *Spring Chinook salmon*

Biologists generally believe the White Salmon spring Chinook salmon population was historically significant, but declined to low numbers after construction of Condit Dam (LCFRB 2004). Fulton (1968) speculated that Chinook salmon historically caught by tribal members upstream of Husum Falls were likely spring Chinook salmon, citing Bryant (1949) and USFWS (1951) but these reports did not indicate direct observations of spring Chinook salmon. Evermann and Meek (1898) surveyed the White Salmon River in August and September and did not observe Chinook salmon in August, however, the conditions were not conducive to observation due to flooding from the CR, and only the lower mile of the river was investigated. If the life history timing of the White Salmon spring Chinook salmon were similar to other LCR spring Chinook salmon populations, adult spring Chinook salmon would be expected to be on the spawning grounds in the upper river during the month of August, not entering their natal river. Lane and Lane Associates (1981) document early indications of the presence or absence of spring Chinook salmon in the White Salmon River. Some of the persons interviewed remembered the presence of spring Chinook salmon, while others could not verify these observations. The W/LC TRT deduced that there was an historical population of spring Chinook salmon in the White Salmon River (Myers et al. 2006).

LeMier and Smith (1955) evaluated the capacity of the White Salmon River to support salmon if passage was provided upstream of Condit Dam. Under conditions existing in 1955, they estimated the White Salmon River could support 732 spring Chinook salmon and 452 fall Chinook salmon, but noted that conditions in the White Salmon River were degraded substantially in 1955 relative to historical levels. Chapman (1981), using instream flow measurements, estimated that in pristine conditions prior to the construction of Condit Dam the White Salmon River supported 625 adult Chinook salmon (spring and fall runs combined). Using similar methods, Young and Rybak (1987) estimated that the habitat upstream of Northwestern Reservoir could support 35,000 spring Chinook salmon smolts, and from 140 to 1,120 spring Chinook salmon adults. Chapman (1981) and Young and Rybak (1987) noted that the watershed has cool summer water temperatures and deep canyon pools, conducive to spring Chinook salmon holding and rearing. The EDT modeling effort estimated capacity for approximately 560 to 650 spring Chinook salmon in the watershed. W/LC TRT members generally believe that the construction of Condit Dam extirpated spring Chinook salmon in the White Salmon River and eliminated the genetic resources of the population (McElhany et al. 2004, p. 71). As recently as 2009, stray hatchery spring Chinook salmon have been observed holding and spawning below Condit Dam, but their reproductive success is unknown (McElhany et al. 2004; NPCC 2004; Engle et al. 2010).

## Spatial Structure and Diversity

Prior to the construction of Condit Dam, spring Chinook salmon probably ranged up the White Salmon River to above Husum Falls, RM 12, and probably up to Big Brother Falls at RM 16.2 (Chapman 1981; Young and Rybak 1987). They may have also migrated into Rattlesnake Creek (NPCC 2004). Fall Chinook salmon were limited to spawning and rearing habitat below Husum Falls (NPCC 2004). This conclusion was confirmed using Radio-tagged adult fall Chinook salmon released above Condit Dam (Engle and Skalicky 2009).

Since 1913, Condit Dam has limited distribution for Chinook salmon to the 3.3-mile area below the dam. While the dam was in place, Chinook salmon spawned and reared in the lower White Salmon River below Condit Dam, (Figure 2.8). Most of these spawners were fall Chinook salmon and many were hatchery strays. In 2011, fisheries co-managers transported and released upstream of Northwestern Lake naturally spawning Chinook salmon entering the White Salmon River in order to preserve the year class. Any redds present downstream of the dam when it was breached would have been destroyed though scour and subsequent deposition of sediments.

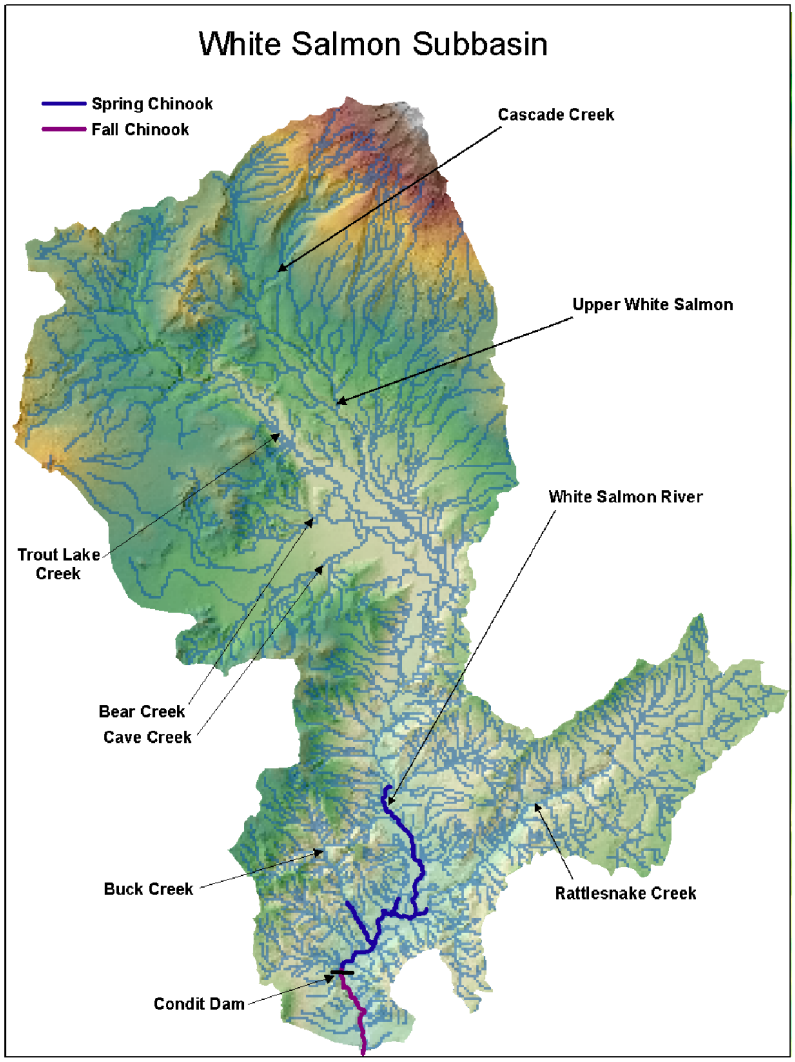


**Figure 2-8. Possible extent of historic spawning distribution of Chinook salmon in the White Salmon River (NPCC 2004)**

### Key Habitat during Different Life Stages

Biologists consider White Salmon River fall-run Chinook salmon an ocean-type salmon because they migrate to the ocean as subyearlings. Tule Chinook salmon begin entering the CR in early August, with the greatest abundance in the estuary between late August and early September. Tule counts at Bonneville Dam generally peak between September 4 and

September 9. Most tules mature at age three, with very few five-year-olds. Fall Chinook salmon spawning in the White Salmon River peaks in late September through early October. The adults tend to spawn in mainstem rivers and large tributaries.

Since human activities have extirpated native spring-run Chinook salmon in the White Salmon River, scientists know little about their life history. Biologists would expect the historical spring-run Chinook salmon population to have a life history similar to other LCR ESU spring Chinook salmon populations. These spring Chinook salmon are a stream type because they primarily smolt as yearlings. Fecundity varies within and among Chinook salmon populations. Adult spring-run Chinook salmon enter the Columbia River from February to Mid-May and spawn from late July to late September (Fulton 1968).

Both fall and spring Chinook salmon generally spawn in stream reaches at least 10 feet wide. They construct redds in gravel and small cobble substrate in pool tailouts, riffles, and glides. Eggs remain in the gravel until emergence, which occurs from February to April depending on water temperatures. Emerging fry seek out shallow, low velocity areas in the stream channel, preferring backwater and dammed pools, along with glides. Shortly after fry colonization, however, tule fall Chinook salmon juveniles begin their outmigration, while the spring Chinook salmon juveniles can continue rearing until October. During the inactive or overwintering life stage, spring Chinook salmon juveniles prefer non-turbulent deeper water habitat types (primary pools) in the main channel, but also use slower portions of large cobble riffles. Yearling spring Chinook salmon outmigrate during the following spring.

Table 2-1 shows key habitat for fall and spring Chinook salmon during different life stages.

**Table 2-1. Key habitat by life stage and time period for fall/spring Chinook salmon (NPCC 2004)**

| Life Stage | Relevant Months | Key Habitat Descriptions |
|---|---|---|
| **Spawning** | Tule Sep-Oct<br>Spring Aug-Sep | Riffles, tailouts, and the swifter areas in glides containing a mixture of gravel and cobble sizes with flow of sufficient depth for spawning activity |
| **Incubation** | Aug-May | Riffles, tailouts, and the swifter areas of glides as described for spawning with sufficient flow for egg and alevin development |
| **Fry Colonization** | Feb-May | Shallow, slow velocity areas within the stream channel, including backwater areas, often associated with stream margins and back eddies and usually in relatively low gradient reaches |
| **Active Rearing** | Tule Feb-June<br>Spring Mar-Oct | Relatively slow water habitat types, often near velocity shears, often associated with relatively low gradient stream channel reaches, including primary pools, backwaters, tailouts, glides, and beaver ponds |
| **Inactive Rearing** | Oct-Mar | Non-turbulent habitat types, particularly deeper water types within the main channel, but also including slower portions of large cobble riffles |
| **Migrant** | Tule, Age 0 Mar-Jun<br>Spring, Age 1 Mar-May | All habitat types having sufficient flow for free movement of juvenile migrants |

| Life Stage | Relevant Months | Key Habitat Descriptions |
|---|---|---|
| **Pre-spawning Migrant** | Tule Aug-Oct<br>Spring Feb-Sep | All habitat types having sufficient flow for free movement of sexually mature adult migrants |
| **Pre-spawning Holding** | Tule Aug-Oct<br>Spring Aug-Sep | Relatively slow, deep water habitat types typically associated with (or immediately adjacent to) the main channel |

### 2.4.2 White Salmon River coho salmon

Myers et al. (2006) included the historic coho salmon population in the White Salmon River as part of the Gorge Stratum within the lower Columbia coho salmon ESU. This section describes the White Salmon River coho salmon population.

#### Abundance and Productivity

The W/LC TRT determined that coho salmon are native to the White Salmon River based on habitat and historical presence of coho salmon in other CR gorge tributaries (Myers et al. 2006). Rich (1938) indicated that only a very small portion of the total CR coho salmon run migrated beyond Bonneville Dam. None of the early surveys of fisheries identified coho salmon in the White Salmon River, although the timing of these surveys did not coincide with coho salmon presence. Interviews with long-term residents and notes found in diaries indicate that coho salmon were likely present, but in low numbers (Lane and Lane Associates 1981; Cobb 1924).

Chapman (1981), using instream flow measurements, estimated that in pristine conditions prior to the construction of Condit Dam the White Salmon River supported 5,489 adult coho salmon. Young and Rybak (1987) estimated that the habitat could support 45,000 coho salmon smolts, and from 1,600 to 2,300 coho salmon adults. Scientists consider the current population in the White Salmon River extirpated (Johnson et al. 1991; Weitkamp et al. 1995; Schiewe 1996; Good et al. 2005). Good et al. (2005) suggested that recovery efforts could use existing hatchery programs to build naturally spawning populations. Currently, the size of this population is unknown. In a 2004 population status evaluation, W/LC TRT members found insufficient data to determine the productivity and abundance of the White Salmon River coho salmon population (McElhany et al. 2004). Some members noted that construction of Condit Dam probably resulted in the population's extirpation, as most historical spawning habitat for the population lies above the dam. Myers et al. (2006) in designating the historical population structure for coho salmon in the Gorge strata identified two populations above Bonneville Dam: Oregon tributaries and Hood River and Washington tributaries and the White Salmon River (including the Wind River, Spring Creek, and the LWS River).

The LCFRB Recovery Plan (LCFRB 2004) proposed an abundance goal for recovery of 150 fish. However, potential production estimates for coho salmon in the White Salmon River, completed for the NPCC subbasin planning (Allen and Connolly 2005; NPCC 2004) and for other efforts (Chapman et al. 1990; Washington Department of Fisheries (WDF) 1990) suggest that the drainage could support 950 to 2,300 coho salmon, if decision makers and scientists are able to restore passage to historical habitats above the dam.

#### Spatial Structure and Diversity

With the removal of Condit Dam, habitat that could potentially support coho salmon extends from the mouth up to RM 14 in the mainstem and into Buck, Spring, Indian, and Rattlesnake creeks (Figure 2-8) (NPCC 2004). This range may provide up to 21 miles of spawning and rearing habitat for coho salmon, with most potential spawning habitat above the location of

the former Condit Dam. Prior to breaching the dam, hatchery strays occasionally use the area below Condit Dam (NPCC 2004).

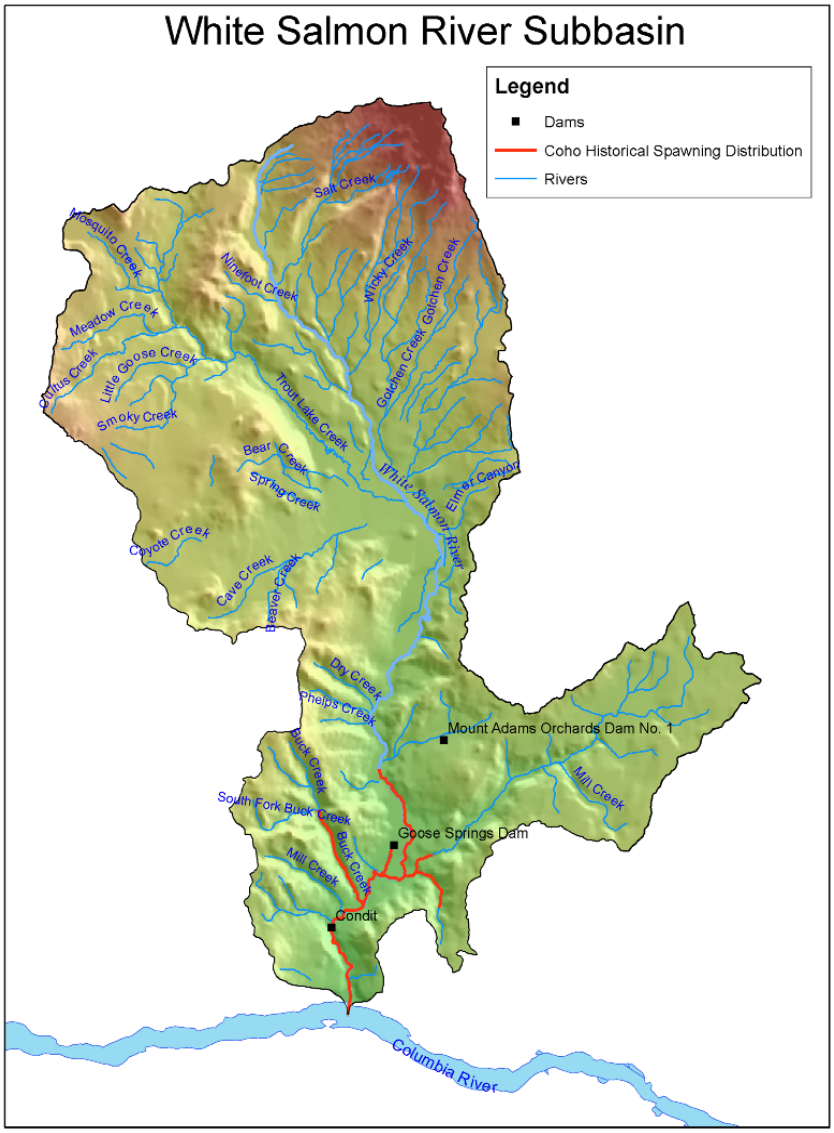


**Figure 2-9. Potential extent of historical spawning distribution of coho salmon in the White Salmon River (McElhany et al. 2004)**

### Key Habitat during Different Life Stages

LCR coho salmon adults typically return to their spawning rivers from September through November, and typically spawn from October through January, with peak activity in November. Redds are constructed in gravel and small cobble substrate in pool tailouts, riffles, and glides, with sufficient flow depth for spawning activity. The eggs incubate in the gravel from October to May and generally emerge from February to April, depending on water temperatures. Emerging fry migrate to shallow, low velocity areas, which are associated with stream margins and back eddies.

After fry colonization, juvenile coho salmon seek out slow water habitat types near velocity shears, which are often associated with relatively low gradient stream reaches where they continue rearing until October. Preferred areas are primarily backwater and dammed pools. As winter approaches, juveniles become inactive and prefer off channel pool habitat over primary pool habitat for overwintering. Coho salmon yearling migration occurs the following spring, peaking in May.

Table 2-2 describes key habitat by life stage.

**Table 2-2. Key habitat by life stage and time period for White Salmon River coho salmon (NPCC 2004)**

| Life Stage | Relevant Months | Key Habitat Descriptions |
|---|---|---|
| **Spawning** | Oct-Jan | Riffles, tailouts, and the swifter areas in glides containing a mixture of gravel and cobble sizes with flow of sufficient depth for spawning activity |
| **Incubation** | Oct-May | Riffles, tailouts, and the swifter areas of glides as described for spawning with sufficient flow for egg and alevin development |
| **Fry Colonization** | Mar-May | Shallow, slow velocity areas within the stream channel, including backwater areas, often associated with stream margins and back eddies and usually in relatively low gradient reaches |
| **Active Rearing** | 0-age Mar-Oct<br>1-age Mar-May | Relatively slow water habitat types, often near velocity shears, often associated with relatively low gradient stream channel reaches, including primary pools, backwaters, tailouts, glides, and beaver ponds |
| **Inactive Rearing** | Oct-Mar | Non-turbulent habitat types, particularly deeper water types within the main channel, but also including slower portions of large cobble riffles |
| **Migrant** | Mar-May | All habitat types having sufficient flow for free movement of juvenile migrants |
| **Pre-spawning Migrant** | Sep-Nov | All habitat types having sufficient flow for free movement of sexually mature adult migrants |
| **Pre-spawning Holding** | Oct-Dec | Relatively slow, deep water habitat types typically associated with (or immediately adjacent to) the main channel |

### 2.4.3 Upper Gorge chum salmon

This section describes the segment of the upper Gorge chum salmon population that historically occupied the White Salmon River.

**Abundance and Productivity**

Chum salmon that returned to the White Salmon River were part of the upper Gorge Tributaries population (McElhany et al. 2004). Annual fish passage reports by the U.S. Army Corps of Engineers (USACE) (2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008), for Bonneville Dam provided data that adult chum salmon continue to pass upstream of Bonneville Dam, with adult counts averaging 139 from 2000 to 2008 and ranging from a

low of 49 to a high of 411. Recent chum salmon surveys by WDFW have identified fewer than five chum salmon carcasses above Bonneville Dam annually; no carcasses were observed in 2005 (Jenkins 2006), however researchers in Oregon observed chum salmon spawning at the mouth of Eagle Creek above Bonneville Dam in 2008 and 2009 (M. Weeber, personal communication 2010). Today, chum salmon are limited almost exclusively to habitats downstream of Bonneville Dam, with most spawning in Washington waters.

Biologists know little about the chum salmon production potential of the LCR or the White Salmon River. Chum salmon fecundity data are variable. In North America, the literature reports individual fecundity ranged from 2,018 to 3,977 eggs per female (Salo 1991). Fecundity data are available for wild chum salmon in the LCR, but not for the White Salmon River. Chum salmon broodstock collected from the lower Gorge population in 2007 had an average fecundity of 2,255 eggs and a range of 1,630 to 2,922 eggs (Hillson 2009).

In the upper Gorge Tributaries population, researchers assumed a 96 percent reduction in abundance due to the existence and operation of Bonneville Dam. They assumed impacts to be predominantly due to inundation of historical habitat by the reservoir (see spatial structure and diversity below), but to include about 5 percent passage mortality for juveniles and an additional 3 percent for adults (Tables 14-1 and 14-2 in NMFS 2008b).

### Spatial Structure and Diversity

Small et al. (2006) analyzed genetic samples from populations in the coast, cascade, and gorge regions of the CR chum salmon ESU. They found significant heterogeneity in genotype distributions between zones and that collections formed regional groups in a neighbor joining tree. Cascade collections had higher allelic richness and private alleles, and the Cowlitz River supported genetically divergent fall and summer runs, the only summer chum salmon run extant in the CR drainage. They propose that chum salmon in the Cascade zone are remnants of original populations and they attributed the divergence between zonal groups to diverse ecological conditions in each zone, which promoted regional genetic adaptation, and to genetic drift experienced in small populations. No information is available regarding the historical diversity for chum salmon in the White Salmon River.

In the White Salmon River, the pool behind Bonneville Dam has inundated approximately 80 percent of the historical chum salmon spawning habitat, rendering it unusable (NPPC 2004).

### Key Habitat during Different Life Stages

Chum salmon usually spawn in lower river reaches, dig their redds in the mainstem, tributaries or in side channels and tend to use shallower, slower running streams and side channels more frequently than do other salmonids. Water velocity in spawning areas varies widely for chum salmon. In Washington, Johnson et al. (1991) measured water velocities near 1,000 chum salmon redds and found that velocities where fish spawned varied from 0.0 to 5.5 ft/sec (0.0 to 167.6 cm/sec), and that over 80 percent of the fish spawned in velocities between 0.7 and 2.7 ft/sec (21.3 and 83.8 cm/sec). This range is similar to that found in other species of salmon.

One detectable difference between chum salmon populations in different areas is the time it takes for eggs to incubate, hatch, and emerge as alevins from the gravel. Differences

between populations are caused by physical factors such as stream flow, water temperature, dissolved oxygen, and gravel composition, and by such biotic factors as genetics, spawning time, and spawning density, all of which can affect survival (reviewed in Bakkala 1970; Salo 1991). Scientists believe water temperature has the most influence on the rate of embryonic development in chum salmon (reviewed in Bakkala 1970; Koski 1975; Salo 1991). The amount of heat, measured in Thermal Units (TUs), required by fertilized chum salmon eggs to develop and hatch is about 400-600 TUs, and the heat required to complete yolk absorption is about 700-1,000 TUs. Lower water temperatures can prolong the time required from fertilization to hatching by 1.5-4.5 months.

Chum salmon do not typically have substantial freshwater rearing time. Most chum salmon juveniles begin seaward migration with minimal time spent in natal streams. Consequently, the period of estuarine residence appears to be the most critical phase in the life history of chum salmon and may play a major role in determining the size of the subsequent adult-run back to fresh water. Chum salmon juveniles, like other anadromous salmonids, use estuaries to feed before beginning long distance oceanic migrations. However, chum salmon and ocean-type Chinook salmon usually have longer residence times in estuaries than do other anadromous salmonids (Dorcey et al. 1978; Healey 1982).

Biologists know little about the seaward migration of juvenile chum salmon from the Columbia River. Generally, however, researchers find migration of chum salmon juveniles out of estuaries appears to closely correlate with prey availability (LCFRB 2004). For information about conditions in the CR Estuary and how chum salmon may be affected, see the Proposed CR Estuary ESA Recovery Plan Module for Salmon & Steelhead http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Estuary-Module.cfm (accessed April 11, 2012).

### 2.4.4 White Salmon River steelhead

*Oncorhynchus mykiss*, of which steelhead and rainbow trout are members, displays a wide variety of life history strategies (Busby et al. 1996). Anadromy is not obligatory in *O. mykiss*, but scientists extensively debate the heritability of anadromy (Rounsefell 1958; Mullan et al. 1992). Progeny of anadromous steelhead can spend their entire lives in freshwater (residualize), while progeny of rainbow trout can migrate seaward. The White Salmon River watershed supports both forms of *O. mykiss*. Although rainbow trout are not in the MCR steelhead DPS, genetic analysis shows that White Salmon steelhead and rainbow trout are an inland race of *O. mykiss* (Phelps et al. 1990; Phelps et al. 1994). The White Salmon population is as part of the Cascade Eastern Slope Tributaries MPG (Figure 2-10).

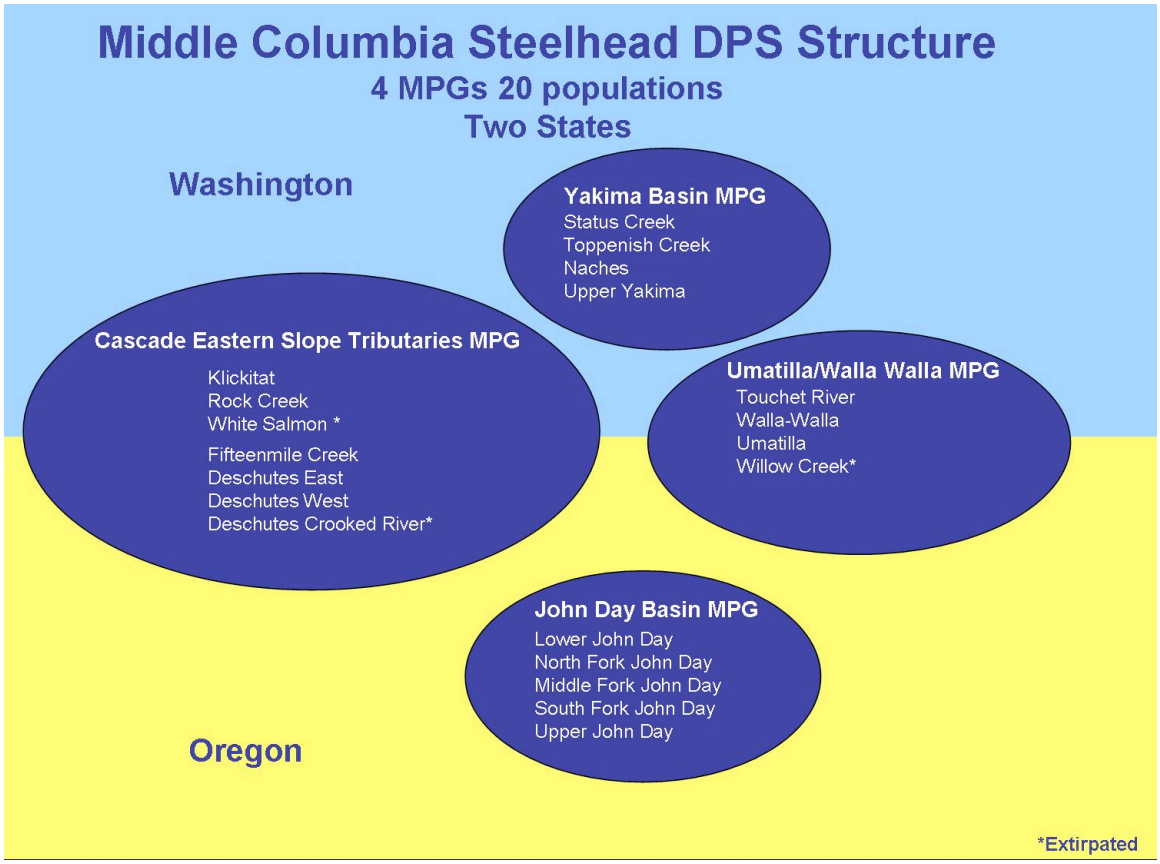


**Figure 2-10. Major Population Groups (MPGs) and populations of middle Columbia steelhead. Note the White Salmon steelhead population is considered functionally extirpated (ICTRT 2007b)**

Some biologists believe that residual steelhead populations in the form of resident trout may contribute to anadromy in the watershed. Phelps et al. (1990) found that introgression from hatchery rainbow plants was not evident in wild rainbow trout samples and high levels of genetic diversity still exist in this population. Seiler and Neuhauser (1985) caught more steelhead smolts than were predicted by the modeling. One hypothesis is that resident rainbow trout spawning upstream of the former Condit Dam continue to produce some steelhead smolts, indicating that anadromous *O. mykiss* has maintained genetic diversity and fitness (NPCC 2004).

Pre-removal monitoring in the White Salmon River above Condit Dam has identified *O. mykiss* juveniles displaying smolt behavior and morphology, and PIT-tagged juveniles have been detected passing Bonneville Dam with one being recovered at the tern colony on East Sand Island (B. Allen, personal communication, 2007). In addition, a juvenile *O. mykiss* PIT-tagged above Condit Dam September of 2004 at 98 mm was detected ascending Bonneville Dam in July of 2006. Genetic analysis of juvenile *O. mykiss* collected in the upper watershed above Husum Falls are different from hatchery trout released in the basin, however additional samples are needed to confirm this finding (Allen et al. 2006). This information supports the theory that even though the population is functionally extirpated

there is still the potential for re-establishing anadromous steelhead in the White Salmon River Basin.

Biologists divide steelhead into two basic run types based on the salmonid species' level of sexual maturity at the time they enter fresh water and the duration of the spawning migration. The stream maturing type, or summer steelhead, enters fresh water in a sexually immature condition and requires several months in fresh water to mature and spawn. The ocean-maturing type, or winter steelhead, enters fresh water with well-developed gonads and spawns relatively shortly after river entry (Bambrick et al. 2004). Based on habitat conditions and the composition of nearby populations, it is likely that the White Salmon River population historically supported both summer and winter life history patterns (ICTRT 2008). Chapman (1981), using instream flow measurements, estimated that in pristine conditions prior to the construction of Condit Dam, the White Salmon River supported 763 adult steelhead. Young and Rybak (1987) estimated that the habitat could support 39,000 steelhead smolts, and 2,770 adults.

### Key Habitat during Different Life Stages

Steelhead generally return to the White Salmon River between April and October, although some hold over in the CR throughout the year and enter the river as they approach spawning. Wild steelhead spawn from February to June with peak spawning in April. Hatchery-reared summer steelhead in the White Salmon River watershed, however, typically spawn earlier, from December to February, with peak activity in January. Steelhead spawning and rearing currently occurs in the lower White Salmon and will occur in both mainstem and tributary habitats after dam removal.

Steelhead eggs incubate in their gravel beds for four to seven weeks, depending on water temperature, before hatching. After emergence, the small fry seek shallow, slow velocity areas within the stream channel, often associated with stream margins. As young steelhead mature they move into water with increasing depth and velocities. Juvenile steelhead typically spend two to three years in freshwater before outmigrating to the ocean. They typically move to interstitial spaces between cobble and boulders for cover during the fall, and remain in this habitat until March. In April, they return to a more active rearing life stage and seek out suitable habitat types. Outmigration occurs in spring and typically peaks in early May (NPCC 2004). Table 2-3 shows key habitat for steelhead during different life stages.

Some steelhead are iteroparous (do not die after spawning). A small proportion of repeat spawners, known as kelts, may return to the ocean for a short period and repeat the spawning migration, a life history adaptation that may be fundamental to ensuring population stability. Iteroparity for Mid-Columbia steelhead ranges from reported rates of 2-4 percent above McNary Dam (at RM 292 measured from the mouth of the Columbia) (Busby et al. 1996) up to 17 percent in the unimpounded tributaries below Bonneville Dam (at RM 146.1) (Leider et al. 1986). Iteroparity rates of summer and winter steelhead in the Kalama River, a tributary to the CR below Bonneville Dam have been estimated at 15 percent and 21 percent respectively (Withler 1966; Leider et al. 1986), while repeat spawners in the Hood River, an Oregon tributary in the impounded Bonneville Pool above Bonneville Dam, make up 9

percent of the summer and 13 percent of the winter-run of steelhead (Olsen 2004). The combined sampling from 1979 to 1981 (Howell et al. 1985) and the 2005 adult trapping data from YN and WDFW reported iteroparity rates for Klickitat River steelhead at 3.2 percent. Sampling of adults at the Klickitat River's Lyle Falls Fishway in 2004 and 2005 has indicated repeat spawning rates of 2.9 percent for summer steelhead and 8.8 percent for winters. Most repeat spawners are females. Iteroparity is a life history trait that should be assessed once steelhead re-colonize the White Salmon River and taken into account when management decisions for White Salmon steelhead are made.

**Table 2-3. Key habitat by life stage and time period for steelhead (NPCC 2004)**

| Life Stage | Relevant Months | Key Habitat Descriptions |
|---|---|---|
| Spawning | Mar-Jun | Riffles, tailouts, and glides containing a mixture of gravel and cobble sizes with flow of sufficient depth for spawning activity |
| Incubation | Mar-Jun | Riffles, tailouts, and glides as described for spawning with sufficient flow for egg and alevin development |
| Fry Colonization | May-Jul | Shallow, slow velocity areas within the stream channel, often associated with stream margins |
| Active Rearing | 0-age May-Jul;<br>1-age, Mar-Oct;<br>2+-age, Mar-Oct | Gravel and cobble substrates with sufficient depth and velocity, and boulder/large cobble/wood obstruction to reduce flow and concentrate food |
| Inactive Rearing | 0,1-age Oct-Mar | Stable cobble/boulder substrates with interstitial spaces |
| Migrant | 1-age, Mar-Jun<br>2+-age, Mar-Jun | All habitat types having sufficient flow for free movement of juvenile migrants |
| Pre-spawning Migrant | Winter, Nov-Apr<br>Summer, All | All habitat types having sufficient flow for free movement of sexually mature adult migrants |
| Pre-spawning Holding | Winter, Dec-May<br>Summer, All | Relatively slow, deep water habitat types typically associated with (or immediately adjacent to) the main channel |

## 2.5 Hatchery Production and Releases

### *Fall Chinook salmon*

No hatchery fall Chinook salmon are released directly in the White Salmon River watershed; however, hatchery tule fall Chinook salmon from Spring Creek NFH do stray into the watershed, contributing to natural production. Fish technicians have also recovered hatchery-origin URB fall Chinook salmon in the White Salmon River. These URB fall Chinook salmon are primarily from the LWS NFH, Bonneville Hatchery, and Klickitat Hatchery programs and are not part of the LCR Chinook salmon ESU. Biologists and recovery planners are considering Spring Creek NFH tule fall Chinook salmon for use in the reintroduction of fall Chinook salmon after PacifiCorp completes decommissioning of Condit Dam. This program is described below.

#### *Spring Creek NFH Tule fall Chinook salmon*

Hatchery managers used fall Chinook salmon from the White Salmon River to establish the Spring Creek NFH fall Chinook salmon program; the hatchery program is part of the LCR Chinook salmon ESU. The program uses only returns to the hatchery for broodstock, but has incorporated other tule stocks in the past. Hatchery workers last released non Spring Creek NFH tule fall Chinook salmon from the hatchery in 1991; the fish were Bonneville tule fall Chinook salmon. The Spring Creek NFH tule fall Chinook salmon is the most representative of the native Chinook salmon population that was historically present in the White Salmon River.

The hatchery program mitigates for lost and degraded habitat because of the construction and operation of the CR hydrosystem by producing locally adapted broodstock for sport, commercial, tribal, and international harvest. The production goal for the current program is for an on-station release of 10,500,000 sub-yearlings annually, with 1,700,000 acclimated and released at the LWS NFH, and 2,800,000 eggs transferred downstream to the Bonneville State Hatchery. This production requires a minimum of 7,000 adults (4,000 females). As mentioned previously, recovery planners are considering fall Chinook salmon from the program for reintroduction into the watershed once decommissioning of Condit Dam is completed. Genetic analysis of naturally spawning fall Chinook salmon in the White Salmon and other Bonneville Pool tributaries determined that Spring Creek NFH fall Chinook salmon are representative of the naturally spawning population of fall Chinook salmon in the White Salmon River (Smith et al. 2007; Smith and Engle 2011).

#### *Non ESU Little White Salmon NFH Upriver Bright fall Chinook salmon*

Biologists collected the original source of this stock of URB fall Chinook salmon at the Bonneville State Fish Hatchery. The current source of URB fall Chinook salmon is fish returning to the LWS NFH. The URB fall Chinook salmon stock is not native to the LWS and is not considered part of the LCR Chinook salmon ESU.

The purpose of the hatchery program is to successfully rear and release URB fall Chinook salmon into the LWS, which will mitigate for lost and degraded habitat because of the construction and operation of the CR hydrosystem, meet *U.S. v. Oregon* court agreements,

and provide a 1.7 million fry release in the Yakima River Basin. The program production goal is to release 2.0 million sub-yearling URB fall Chinook salmon at the hatchery, and 2.5 million sub-yearlings that come from the Bonneville State Hatchery and are acclimated for 4 weeks before being released on-station.

***Spring Chinook salmon***

Presently there are no hatchery programs associated with this population, however hatchery spring Chinook salmon have been observed spawning in the White Salmon River. In 2009, biologists examined 110 spring Chinook salmon carcasses at a weir installed at RM 1.1 at the White Salmon Ponds fish facility downstream of Condit Dam (Engle et al. 2010). All the spring Chinook salmon carcasses were hatchery-origin and post-spawn, i.e., near death or in a state of decay (Engle et al. 2010). The lack of natural-origin spring Chinook salmon examined at the weir supports the observation that spawning does occur in the lower White Salmon River but rearing habitat is lacking (Engle et al. 2010).

***Coho salmon***

There are no hatchery programs that directly release hatchery coho salmon into the White Salmon River. The coho salmon program at the LWS NFH released coho salmon that may have contributed to straying into the White Salmon River in the past, but stray rates were not estimated. The LWS NFH discontinued the program after releases in 2004 because of funding shortfalls. Stray coho salmon currently entering the White Salmon River may come from releases in the Klickitat and Umatilla rivers and from Bonneville Hatchery.

***Chum salmon***

Historical and current hatchery influences on chum salmon are minimal. Hatcheries have released chum salmon into only 4 of 10 Washington populations. Hatchery fish do not comprise a substantial fraction of any naturally spawning chum salmon population and all originate from local wild populations. Current chum salmon hatchery programs focus on reintroduction (Chinook River) and conservation (Duncan Creek, and Grays River) (LCFRB 2004).

***Steelhead***

Scientists and recovery planners do not consider the hatchery programs in the White Salmon River watershed to be part of the MCR steelhead DPS. From 1995 to 2010, fisheries co-managers annually released both summer and winter steelhead smolts from broodstock collected at the Skamania Hatchery on the West Fork of the Washougal River into the White Salmon River below Condit Dam. The summer steelhead broodstock derives from summer steelhead from the Washougal and Klickitat Rivers. The winter steelhead broodstock derives from returns to the Washougal River.

The Skamania Hatchery program goal was to provide fisheries for summer and winter steelhead in the White Salmon River as mitigation for losses from human development and concomitant habitat loss and to meet the obligations of the *U.S. v. Oregon* agreement. The program involved an annual release of 24,000 summer and 20,000 winter steelhead smolts, although actual releases varied from year to year. Production consisted of adipose-fin-clipped fish to allow for selective fisheries and to facilitate assessment of the ratio of

hatchery adults to wild adults. Workers trucked smolts from Skamania Hatchery and stream-released them into the White Salmon River at RM 1.5. Fish managers terminated the program with the 2009 releases.

Biologists would need to develop or identify a more suitable broodstock to expedite the reintroduction of steelhead in habitats upstream of the former Condit Dam. Monitoring steelhead escapement and production, after dam decommissioning is complete, will determine whether there are impacts from these Skamania Hatchery releases.

## 2.6 Harvest

Primarily ocean and mainstem CR commercial, tribal, and sport intercept Chinook salmon and coho salmon. Tributary sport fisheries also harvest some Chinook salmon and coho salmon. The LCFRB recovery plan (LCFRB 2004) and the ESA section 7 Biological Opinion for fisheries managed under the *U.S. v. Oregon* Agreement (NMFS 2008c) describe in detail harvest management and harvest effects.

In 2012, the fisheries regulations in the White Salmon River prohibited the retention of unmarked Chinook salmon from April 1 to July 31, and unmarked Chinook salmon and coho salmon from August 1 to March 31, in the area from the mouth to the Northwestern Lake Road bridge (WDFW 2012).During the removal of Condit Dam the White Salmon was closed to fishing from the Northwestern Lake Road bridge downstream to the old county road bridge below the powerhouse. Regulations also prohibit the retention of chum salmon in tributary recreational fisheries.

Steelhead harvest, while locally important, was historically likely less substantial than salmon harvest because of lower abundance and spawning times that coincided with higher flows (NPCC 2004). The YN reports that tribal members fished for salmon and steelhead historically as high as Husum Falls and Rattlesnake Falls on the White Salmon River (J. Meninick, YN Cultural Resources Department, personal communication, 2006). Section 5.4, Harvest, for an expanded discussion of harvest impacts.

# 3 Recovery Goals and Viability Criteria

The primary goal of ESA recovery plans is for the species to reach the point that it no longer needs the protection of the Act, i.e., NMFS delists the species. Recovery plans may also contain "broad-sense goals," defined in the recovery planning process as going beyond the requirements for delisting to address, for example, other legislative mandates or social, economic, and ecological values.

NMFS applies the delisting criteria at the ESU/DPS level based on determinations of the viability of the independent populations that make up the ESU/DPS. The LCR ESA Recovery Plan describes the criteria for delisting the LCR ESUs. As noted, this Plan is an appendix of the LCR ESA Recovery Plan. The middle Columbia Steelhead ESA Recovery Plan describes the criteria for delisting the MCR Steelhead DPS. This plan is also an appendix to the middle Columbia Steelhead ESA Recovery Plan. This chapter provides recovery goals for the White Salmon River Chinook salmon, coho, chum salmon, and steelhead populations and describes the criteria NMFS will use to assess progress toward those goals and the role of the White Salmon River salmon populations in overall ESU/DPS viability.

There are two kinds of criteria that enter into a delisting decision: biological criteria defining viable populations (section 3.2, Biological Viability Criteria) and "threats" criteria related to the five listing factors detailed in the ESA (section 3.3, Threats Criteria). The threats criteria define the conditions under which NMFS can determine that responsible parties have addressed or mitigated the listing factors or threats. Together these make up the "objective, measurable criteria" required under section 4(f)(1)(B). This chapter discusses both kinds of criteria.

## 3.1 Recovery Goals

The primary goal of this plan is for the White Salmon River salmon and steelhead populations to contribute to the delisting of the LCR ESUs and the MCR Steelhead DPS. McElhany et al. (2000) defines a VSP as an independent population that has negligible risk of extinction over a 100-year timeframe. However, all populations within an ESU or DPS do not have to reach viable status for NMFS to delist the ESU/DPS (section 3.2.2, DPS and MPG Viability Criteria).

The visions, goals, and actions of many of the parties involved in the White Salmon recovery planning process may go beyond ESA delisting. The vision for broad-sense recovery incorporates ESA delisting goals in the sense that NMFS could delist White Salmon River salmon and steelhead during an extended and stepwise process of achieving broad-sense recovery goals. Broad-sense recovery goals incorporate many of the local and traditional uses, including those associated with rural and Native American values, which are important in the Pacific Northwest.

The proposed local, collaborative recovery board may choose to define additional, broad-sense goals for the White Salmon River watershed and other areas within the Washington Gorge Management Unit. The board's broad-sense goals for the area would likely build upon direction already adopted by various stakeholders in the area. These goals would then

guide the board as it defines and implements future recovery actions for the White Salmon River watershed.

## 3.2 Biological Viability Criteria

One of the main tasks assigned to the TRTs was to develop biologically based criteria for determining the viability of ESA listed salmon and steelhead. Viability criteria identify characteristics and conditions that, when met, describe viable populations and a viable ESU or DPS.

The TRTs based their approaches to recovery on guidance from the NMFS Technical Memorandum *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). This memorandum provides general direction for setting viability objectives at the ESU/DPS and component population levels. VSP guidelines provided by McElhany et al. (2000) recommend that a viable DPS population should be large enough to:

- Have a high probability of surviving variation observed in the past and expected future
- Be resilient to environmental and anthropogenic disturbances
- Maintain genetic diversity
- Support/provide ecosystem functions

NMFS organized the viability guidelines provided by McElhany et al. (2000 around four major considerations: abundance, productivity, spatial structure, and diversity. ESU/DPS-level viability criteria consider the appropriate distribution and characteristics of component populations to maintain the ESU/DPS in the face of longer-term ecological and evolutionary processes (ICTRT 2005a). The viability criteria defined by the ICTRT and W/LC TRT have been adopted as the biological criteria for delisting of the ESUs and DPS that include the listed White Salmon populations discussed in this Plan.

### 3.2.1 ESU/DPS Viability Criteria

#### Defining ESU and DPS Structure

The TRTs applied overall ESU/DPS-level viability criteria based on smaller units of MPG and independent populations to determine paths toward viability. Central to this approach is the recognition that salmonid population structure is hierarchical. The TRT based the biological criteria for populations and ESU/DPS-level viability on the existence of a biological hierarchy that spans ESUs/DPSs, major groupings, populations, and substructure within populations (Figure 3-1). The approach recognizes that historical salmonid populations within an ESU or DPS retain some genetic similarities because they move between different habitats during their life cycle. This distribution across the landscape and the diverse genetic, life history and morphological characteristics that evolve/contribute significantly to a population's long-term persistence.

- **Evolutionarily Significant Unit:** Two criteria define an ESU or DPS listed under the ESA: 1) it must be substantially reproductively isolated from other conspecific units, 2) it must represent an important component of the evolutionary legacy of the species (Waples 1991).
- **Major Population Grouping:** A group of populations that share similar genetic, geographic (hydrographic), and/or habitat characteristics within an ESU/DPS (ICTRT 2005b). The ICTRT termed this level in the hierarchy a MPG, and the W/LC TRT called it a "stratum." The TRTs consider MPGs, strata, and the "geographic regions" described by the Puget Sound TRT to be analogous.
- **Independent Population:** McElhany et al. (2000) defined an independent population as "…a group of fish of the same species that spawns in a particular lake or stream (or portion thereof) at a particular season and which, to a substantial degree, does not interbreed with fish from any other group spawning in a different place or in the same place at a different season. Groups are considered to be independent populations if they are isolated to such an extent that exchanges of individuals among the populations do not substantially affect the population dynamics or extinction risk of the independent populations over a 100-year time frame."

**Hierarchy in Salmonid Population Structure**

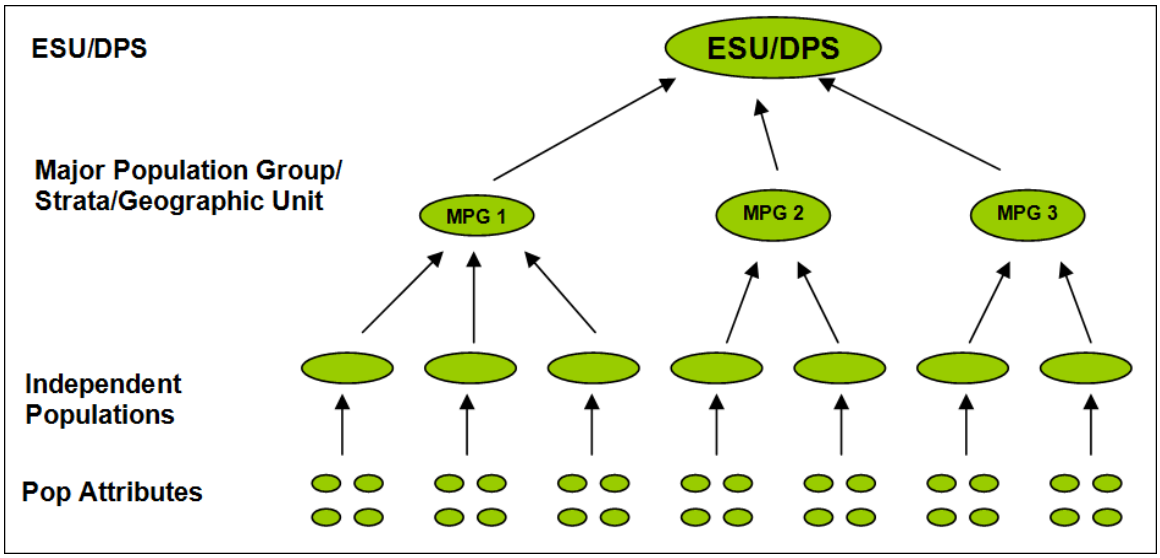


**Figure 3-1. Hierarchical levels of salmonid population structure as defined by the TRTs for ESU/DPS recovery planning**

The TRTs established ESU/DPS-level viability criteria based on the VSP guidelines identified by McElhany et al. (2000). The W/LC TRT identified five essential elements to address in its approach (McElhany et al. 2006). The ICTRT (2007) adapted these five elements for the middle Columbia Steelhead DPS. The five elements are:

**Stratified Approach**: Life history and ecological complexity that historically existed should have a high probability of persistence. The W/LC TRT aggregated populations into MPG, or strata, based on each combination of life history type and ecological zone. The ICTRT stratified the MCR steelhead DPS into groups based on ecoregion characteristics (Eastern Cascades, Columbia Plateau, John Day and Yakima), life history types (summer, winter and summer/winter) and other geographic and genetic considerations.

**Viable Populations**: Some individual populations within a MPG should have persistence probabilities consistent with a high probability of MPG persistence. The W/LC TRT defined high persistence probability based on the presence of at least two populations with a negligible risk of extinction and a strata average of a medium-low risk of extinction. The ICTRT defined high persistence probability based on the presence of at least two or one-half of historical populations with a negligible risk of extinction.

**Representative Populations**: Representative populations must achieve criteria or maintain viability criteria, but not every historical population needs to meet viability criteria. Viable combinations of populations should include "core" populations that are highly productive, "legacy" populations that represent historical genetic diversity, and dispersed populations that minimize susceptibility to catastrophic events.

**Non-deterioration**: No population should be allowed to deteriorate until ESU/DPS recovery is assured, and all extant populations should be maintained. Current populations and population segments should be preserved. Recovery measures will be needed in most areas to arrest declining status and offset the effects of future impacts.

**Safety Factors**: Higher levels of recovery should be attempted in more populations than the minimum needed to achieve ESU/DPS viability because not all attempts will be successful. Recovery efforts should target more than the minimum number of populations and more than the minimum population levels thought to ensure viability. Some populations should be highly viable.

### W/LC TRT Recommended Viability Criteria

The W/LC TRT document, *Interim Report on Viability Criteria for Willamette and Lower Columbia Basin Pacific Salmonids* (McElhany et al. 2003) describes recommended viability criteria for salmon ESUs in the W/LC recovery domain. The LCFRB applied these 2003 criteria to assess viability and develop the recovery direction for the listed White Salmon River Chinook salmon, coho, and chum salmon populations that NMFS and the NPCC adopted as part of the lower Columbia Salmon Recovery and Subbasin Plan (LCFRB 2004). This direction is also included in this recovery plan. Summarized below are the criteria and approach defined by the W/LC TRT in 2003. In 2006, the W/LC TRT (McElhany et al. 2006) revised the 2003 criteria by incorporating new analyses by the W/LC TRT itself, other TRTs and state agencies, among others. The LCFRB and the WAGIT which includes White

Salmon stakeholders will eventually use the new criteria to update goals and status evaluations for Washington populations through the recovery plan revision process. The 2006 revised viability criteria (McElhany et al. 2006) are available at http://www.nwfsc.noaa.gov/trt/wlc/viability_report_revised.cfm (accessed April 11, 2012).

### *Independent Population Viability Criteria*

The W/LC TRT's 2003 viability criteria (McElhany et al. 2003) use five population-level attributes as indicators for viability: 1) adult productivity and abundance, 2) juvenile out-migrant productivity, 3) population diversity, 4) habitat, 5) spatial structure. The 2003 report also provides a set of guidelines for examining viability for each indicator (McElhany et al. 2003). Shown in Table 3-1 are the 2003 viability criteria.

**Table 3-1. Population viability criteria (McElhany et al. 2003; McElhany et al. 2006)**

*Adult Population Productivity and Abundance*

1. In general, viable populations should demonstrate a combination of population growth rate, productivity, and abundance that produces an acceptable probability of population persistence. Various approaches for evaluating population productivity and abundance combinations may be acceptable, but must meet reasonable standards of statistical rigor.
2. A population with a non negative growth rate and an average abundance approximately equivalent to estimated historical average abundance is in the highest persistence category. The estimate of historical abundance should be credible, the estimate of current abundance should be averaged over several generations, and the growth rate should be estimated with adequate statistical confidence. This criterion takes precedence over criteria 1.

*Juvenile Outmigrant Production*

The abundance of naturally produced juvenile migrants should be stable or increasing as measured by observing a median annual growth rate or trend with an acceptable level of confidence.

*Within Population Spatial Structure*

The spatial structure of a population must support the population at the desired productivity, abundance, and diversity levels through short-term environmental perturbations, longer-term environmental oscillations, and natural patterns of disturbance regimes. The metrics and benchmarks for evaluating the adequacy of a population's spatial structure should specifically address:

a. Quantity: Spatial structure should be large enough to support growth and abundance, and diversity criteria.

b. Quality: Underlying habitat spatial structure should be within specified habitat quality limits for life history activities (spawning, rearing, migration, or a combination) taking place within the patches.

c. Connectivity: Spatial structure should have permanent or appropriate seasonal connectivity to allow adequate migration between spawning, rearing, and migration patches.

d. Dynamics: The spatial structure should not deteriorate in its ability to support the population. The processes creating spatial structure are dynamic, so structure will be created and destroyed, but the rate of flux should not exceed the rate of creation over time.

e. Catastrophic Risk: The spatial structure should be geographically distributed in such a way as to minimize the probability of a significant portion of the structure being lost because of a single catastrophic event, either anthropogenic or natural.

*Within Population Diversity*

1. Sufficient life history diversity must exist to sustain a population through short-term environmental perturbations and to provide for long-term evolutionary processes. The metrics and benchmarks for evaluating the diversity of a population should be evaluated over multiple generations and should include:

    a. Substantial proportion of the diversity of a life-history trait(s) that existed historically,

    b. Gene flow and genetic diversity should be similar to historical (natural) levels and origins,

    c. Successful utilization of habitats throughout the range, and

    d. Resilience and adaptation to environmental fluctuations.

*General Habitat*

1. The spatial distribution and productive capacity of freshwater, estuarine, and marine habitats should be sufficient to maintain viable populations identified for recovery.

2. The diversity of habitats for recovered populations should resemble historical conditions given expected natural disturbance regimes (e.g., wildfire, flood, volcanic eruptions, etc.). Historical conditions represent a reasonable template for a viable population; the closer the habitat resembles the historical diversity, the greater the confidence in its ability to support viable populations.

At a large scale, habitats should be protected and restored, with a trend toward an appropriate range of attributes for salmonid viability. Freshwater, estuarine, and marine habitat attributes should be maintained in a non-deteriorating state.

The W/LC TRT's revised criteria, described in their 2006 report *Revised Viability Criteria for Salmon and Steelhead in the Willamette and Lower Columbia Basins* (McElhany et al. 2006), use three population-level attributes as indicators of viability instead of the five identified in 2003. The 2006 attributes are: 1) abundance and productivity, 2) spatial structure, 3) diversity. The revised criteria include juvenile out migrant productivity as a subset of abundance and productivity and address habitat criteria as part of the discussion of listing factors criteria (McElhany et al. 2006).

The W/LC TRT's 2003 system for integrating population attributes to assess population extinction risk used a 0-4 qualitative scale, with zero indicating a population with a low probability of persistence, and four indicating a population with high probability of persistence. The TRT's 2006 report (McElhany et al. 2006) maintains this system (Table 3-2).

**Table 3-2. Population persistence*/viability categories (McElhany et al. 2003; McElhany et al. 2006)**

| *Scale* | *Viability* | *Description* | *Persistence Probability** |
|---|---|---|---|
| **0** | Very Low (VL) | Either extinct or very high risk of extinction | 0-40% |
| **1** | Low (L) | Relatively high risk of extinction | 40-74% |
| **2** | Medium (M) | Medium high risk of extinction | 75-94% |
| **3** | High (H) | Low (negligible) risk of extinction (represents a "viable" level) | 95-99% |
| **4** | Very High (VH) | Very low risk of extinction | >99% |

** 100-year persistence probabilities*

### *Strata and ESU Viability Criteria*

The criteria developed by the W/LC TRT for recovery planning in 2003 state that for an ESU as whole to be viable, all of the historical strata need to have a high probability of persistence (McElhany et al. 2003). The W/LC TRT used ratings of individual population's extinction risk to determine viability at the strata and ESU levels. Table 3-3 shows criteria guidelines identified by the W/LC TRT to complete these evaluations. The TRT maintained its support for the guidelines in its 2006 report (McElhany et al. 2006).

**Table 3-3. Criteria guidelines for determining strata and ESU viability (McElhany et al. 2003, 2006)**

| ESU-Level Criteria Guidelines |
|---|
| 1. Every Stratum (life history and ecological zone combination) that historically existed should have a high probability of persistence |
| **Strata-Level Criteria Guidelines** |
| 1. Individual populations within a stratum should have persistence probabilities consistent with a high probability of strata persistence<br>2. Within a stratum, the populations restored/maintained at viable status or above should be selected to:<br>a. Allow for normative metapopulation process, including the viability of "core" populations that are defined as the historically most productive populations<br>b. Allow for normative evolutionary processes, including the retention of the genetic diversity represented in relatively unmodified historic gene pools<br>c. Minimize susceptibility to catastrophic events |
| **ESU-Level Recovery Strategy Criteria Guidelines** |
| 1. Until all ESU viability criteria have been achieved, no population should be allowed to deteriorate in its probability of persistence<br>2. High levels of recovery should be attempted in more populations than identified in the strata viability criteria because not all attempts will be successful |

## ICTRT Recommended Biological Viability Criteria

The ICTRT developed biologically based viability criteria for ESA-listed salmon and steelhead in the Interior Columbia domain. The ICTRT based its approach to recovery on guidance from the NMFS Technical Memorandum, *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (McElhany et al. 2000). As stated above, this memorandum provides general direction for setting viability objectives at the ESU/DPS and component population levels.

Viability criteria at the population level address four VSP parameters (McElhany et al. 2000):

- *Abundance* - the average number of spawners in a population over a generation or more
- *Productivity* - the performance of a population over time in terms of recruits produced per spawner
- *Spatial Structure* - a population's geographic distribution and the processes that affect that distribution
- *Diversity* - the distribution of genetic, life history, and phenotypic variation within and among populations

The ICTRT grouped specific population-level criteria into two categories to assess viability at the independent population level: measures addressing abundance and productivity, and measures addressing spatial structure and diversity. The viability of an independent population is determined by integrating risks across the four parameters.

The ICTRT's objective for population abundance and productivity is that abundance should be high enough that 1) in combination with intrinsic productivity, declines to critically low levels would be unlikely assuming recent historical patterns of environmental variability; 2) compensatory processes provide resilience to the effects of short-term perturbations; 3) subpopulation structure is maintained (e.g., multiple spawning tributaries, spawning patches, life history patterns) (ICTRT 2005a).

The ICTRT developed criteria for characterizing the relative size and complexity of Interior Columbia Basin steelhead populations based on their analysis of the intrinsic or historical potential habitat available to the population (ICTRT 2005a). This analysis used available Geographic Information System (GIS) data layers showing stream characteristics (e.g. channel width, gradient, and valley confinement) and empirically derived relationships between habitat type, stream structure, landscape processes, and spawning. The ICTRT built a model that also incorporated information from local biologists and recovery planners to identify natural barriers to migration and other local variations.

Mid-Columbia steelhead spawn in a wide range of tributary drainage areas: from small creeks such as Fifteenmile or Rock Creek to very large rivers such as the lower John Day. The ICTRT categorized historical population sizes as Basic, Intermediate, Large, and Very Large, and set minimum abundance thresholds for steelhead populations of each type as follows: Basic: 500 spawners; Intermediate, 1,000 spawners; Large, 1,500 spawners; Very Large, 2,250. The abundance thresholds are associated with minimum productivity thresholds, based on modeling studies described by the ICTRT (March 2007a and November 2007b). Modeling studies link abundance and productivity, within limits: above a certain threshold, higher productivity can compensate for lower abundance and vice versa.

The ICTRT used the concept of the viability curve (ICTRT 2007a, 2007b; McElhany et al. 2006) as a framework for defining population specific abundance and productivity levels to meet the objectives (Figure 3-2). A viability curve describes combinations of abundance and productivity that yield a particular risk threshold. The viability curve links the two parameters relative to extinction risks associated with short-term environmental variability. Given a particular productivity level, larger populations are more resilient in the face of year-to-year variability in overall survival rates than are smaller populations. Populations with relatively high intrinsic productivity (expected ratio of spawners to their parent spawners at low levels of abundance) are also more robust at a given level of abundance than populations with lower intrinsic productivity.

The ICTRT generated viability curves for each population to define the combinations of abundance and productivity corresponding to a range of extinction risks over a 100-year period - less than 1 percent (very low), less than 5 percent (low), less than 25 percent (moderate), and greater than 25 percent (high), see Figure 3-2. It targeted population level recovery strategies to achieve less than a 5 percent (low) risk of extinction in a 100-year period. This is consistent with the VSP guidelines and conservation literature (McElhany et al. 2000; NRC 1995).

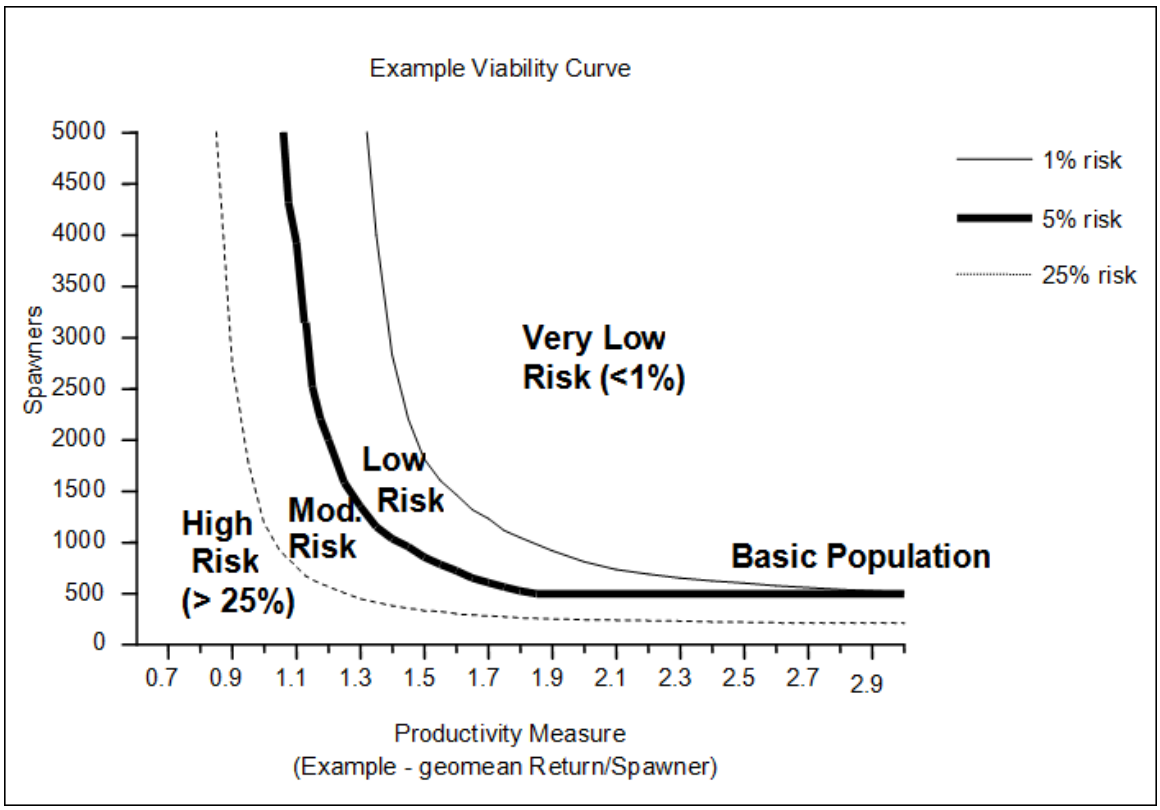


**Figure 3-2. Example of an abundance/productivity viability curve (ICTRT 2007a)**

### 3.2.2 DPS and MPG Viability Criteria

Similar to the W/LCR TRT approach to strata and ESU viability criteria (Table 3-3) the ICTRT (2007) developed criteria based on recovery of MPGs. MPGs are geographically and genetically cohesive population groups, and are critical components of ESU/DPS spatial structure and diversity (Figure 2-10). Having all MPGs within an ESU/DPS at low risk provides the greatest probability of persistence for the ESU/DPS. Thus, the ICTRT criterion for a viable ESU/DPS is that all extant MPGs and any extirpated MPGs critical for proper functioning of the ESU/DPS should be at low risk.

Further, the following five criteria should be met for an MPG to be regarded as at low risk (viable) (ICTRT 2007b):

1. At least one-half of the populations historically within the MPG (with a minimum of two populations) should meet viability standards.
2. At least one population should be classified as “Highly Viable.”
3. Viable populations within an MPG should include some populations classified (based on historical intrinsic potential) as “Very Large," "Large," or “Intermediate,” generally reflecting the proportions historically present within the MPG. In particular, Very Large and Large populations should be at or above their composite historical fraction within each MPG.

4. All major life history strategies (e.g., spring and summer-run timing) that were present historically within the MPG should be represented in populations meeting viability requirements.
5. Remaining MPG populations should be maintained with sufficient abundance, productivity, spatial structure, and diversity to provide for ecological functions and preserve options for ESU/DPS recovery.

***Population Recovery Classifications***

The W/LC TRT and LCFRB used the results of the 2003 Population Viability Criteria report to build a recovery scenario that describes the target status for each population. The W/LC TRT and the LCFRB classified individual populations as *primary* (targeted for restoration to high or high + probability of persistence), *contributing* (targeted for restoration to low or medium probability of persistence), or *stabilizing* (populations that are to be maintained at current levels and likely to have low probabilities of persistence). They identified the following target levels for White Salmon Chinook salmon, coho, and chum salmon. The LCFRB has updated the 2004 recovery plan and proposed to maintain the classifications for all of the White Salmon River populations except coho salmon, which has been elevated to a primary population classification (LCFRB 2010).

### White Salmon River Fall Chinook salmon (Contributing, Medium)

Historically, the tule fall Chinook salmon population in the White Salmon was large. Condit Dam affected the population, although a small amount of fall Chinook salmon habitat was available downstream of the dam and upstream from Bonneville Reservoir inundation. The Spring Creek Hatchery program, which originated from White Salmon River fall Chinook salmon stock, is located three miles downstream of the river mouth and straying of returning hatchery adults to the White Salmon River is consistent with a *contributing* population designation. A tribal fishery targets Spring Creek Hatchery fish near the river mouth. The W/LC TRT and the LCFRB targeted the White Salmon population for medium viability to reflect concerns with hydro impacts (Bonneville and Condit dams) and higher harvest rates associated with combined treaty and non-treaty fisheries. Based on the TRT's findings, the Plan proposed an abundance goal for recovery of 900 fish (LCFRB 2004).

### White Salmon River Spring Chinook salmon (Contributing, Low)

This population was historically significant but is currently extinct. Reintroduction would include use of an outside stock. The best source stock may be from the Klickitat, which is outside the lower Columbia ESU. The W/LC TRT would need to provide criteria for evaluating appropriate source stocks for reintroduction. The low viability target for White Salmon spring Chinook salmon recognizes the long period required to restore a locally adapted natural population from an out-of-basin stock. Based on TRT findings, the Plan proposed an abundance goal for recovery of 400 fish (LCFRB 2004).

### White Salmon River coho salmon (Primary, High)

The White Salmon River coho salmon are part of the Washington upper Gorge Tributaries and White Salmon River population. Lack of access to habitats upstream of Condit Dam

limits current potential for coho salmon production in the White Salmon River. There may be some coho salmon production occurring in the one-mile reach downstream of Condit Dam. Based on TRT findings, the Plan proposed an abundance goal for recovery of 150 fish (LCFRB 2004).

#### Upper Gorge chum salmon, including White Salmon River chum salmon (Contributing, Medium)

The LCFRB identified the entire population of upper Gorge chum salmon to have a very low viability (LCFRB 2004). Bonneville Reservoir inundates most of historical habitat for this population and passage at Bonneville Dam impacts both juvenile and adult migration. The LCFRB proposed an abundance goal for recovery of 600 fish.

#### White Salmon River steelhead (Low Risk)

The ICTRT did not apply the same classification system to MCR steelhead populations but did identify that to be viable, the White Salmon steelhead population needs to reach a minimum abundance threshold of 500 naturally produced spawners with a sufficient intrinsic productivity to achieve a five percent or less risk of extinction over a 100-year timeframe (ICTRT 2007b). The ICTRT recognizes that recovering this functionally extirpated population to a viable level may not be necessary to achieve viability at the MPG and DPS levels.

## 3.3 Threats Criteria

NMFS evaluated listing factors under section 4(a)(1) when the agency made the initial determination to list the species for protection under the ESA. In the future, when NMFS reevaluates the status of the species to determine whether these factors continue to limit recovery, the agency can decide whether the protections of the ESA are still warranted. If no longer warranted, NMFS could delist the species.

At the time of a delisting decision, NMFS will examine whether the entities responsible for recovery have addressed the section 4(a)(1) listing factors. To assist in this examination, NMFS will use the listing factors (or threats) criteria described below in addition to evaluation of biological recovery criteria and other relevant data and policy considerations.

To determine that the affected DPS has recovered to the point that it no longer requires the protections of the ESA, NMFS will review the status of the listing factors according to the specific criteria identified for each of them (see below). The threats need to have been addressed to the point that delisting is not likely to result in their re-emergence. It is possible that current perceived threats will become insignificant in the future as a result of changes in the natural environment or changes in the way threats affect the entire life cycle of salmon. Consequently, as the result of RM&E, NMFS expects that the agency will change the ranking of threats over time and identify new threats. During the 5-year status reviews, NMFS will evaluate and review the listing factor criteria under conditions at the time.

The specific criteria listed below for each of the relevant listing/delisting factors help to ensure that responsible entities address and mitigate the underlying causes of prior to considering a species for delisting. NMFS expects that if the proposed actions described in

the Plan are implemented, they will make substantial progress toward meeting the following listing factor (threats) criteria:

**Factor A: The present or threatened destruction, modification, or curtailment of its habitat or range**

To determine that the ESU or DPS is recovered, threats to habitat should be addressed to a degree sufficient to support a viable ESU or DPS as outlined below:

1. Impaired fish passage (e.g., dams and culverts) is addressed, either through removal or modification of obstructions, to improve survival and restore access to historically accessible habitat where necessary to support recovery goals.
2. Flow conditions that support sufficient salmonid rearing, spawning, and migration of a viable ESU or DPS are achieved, where possible, through management of White Salmon River mainstem and tributary irrigation operations, and through the improvement of other water user efficiencies and conservation, including for municipal supply and other consumptive purposes.
3. Forest management practices that protect watershed and stream functions are implemented on Federal, state, tribal, and private lands.
4. Agricultural best management practices, including grazing, are implemented to protect and restore riparian areas, floodplains, and stream channels, and to protect water quality from sediment, pesticide, herbicide, and fertilizer runoff.
5. Urban and rural development, including land use conversion from agriculture and forestland to residential uses, avoids impairment of water quality or impairment of natural stream conditions.
6. The effects of toxic contaminants on salmonid fitness and survival in the White Salmon mainstem and tributaries are sufficiently limited so as not to affect recovery.
7. Channel function, including vegetated riparian areas, canopy cover, streambank stability, off-channel and side-channel habitats, natural substrate and sediment processes, and channel complexity, is restored to provide adequate rearing and spawning habitat.
8. Floodplain function and the availability of floodplain habitats for salmon are restored to a degree sufficient to support a viable ESU/DPS. This restoration should include connectivity between river and floodplain and the restoration of altered sediment routing.
9. Water operations management in the mainstem White Salmon and tributaries maximize survival of juvenile rearing, emigrating smolts, and immigrating and spawning adults.

**Factor B: Over-utilization for commercial, recreational, scientific or educational purposes**

To determine that the ESU or DPS is recovered, any utilization for commercial, recreational, scientific, or educational purposes should be managed as outlined below:

1. Fishery management plans for salmon are in place that (a) accurately account for total fishery mortality (i.e., both landed catch and non-landed mortalities) and constrain mortality rates to levels that are consistent with achieving population viability (i.e., provide for adequate spawning escapement given their productivity); (b) are implemented in such a way as to avoid deleterious genetic effects on populations or negatively affect the distribution of populations.
2. Federal, state, and tribal fishing rules and regulations are effectively enforced.
3. Technical tools accurately assess the effects of the harvest regimes so that harvest objectives are met but not exceeded.
4. Scientific handling of fish from adult and juvenile trapping operations is minimized to reduce indirect mortalities associated with education or scientific programs, while recognizing that monitoring, research, and education are key actions for conservation of the species.
5. To the degree sufficient to support a viable ESU or DPS, routine instream construction and maintenance practices are implemented in a manner to reduce or eliminate mortality of listed species.

**Factor C: Disease or predation**

To determine that the DPS is recovered, any disease or predation that threatens its continued existence should be addressed as outlined below:

1. Hatchery operations do not subject salmon populations to deleterious diseases and parasites and do not result in increased predation rates of wild salmon.
2. Predation by avian predators is managed in a way that promotes recovery of salmon populations.
3. The northern pike minnow are managed to reduce predation on salmon to a degree sufficient to meet recovery goals.
4. Populations of introduced smallmouth bass, walleye, and catfish are managed such that competition or predation does not impede salmon recovery. Predation by marine mammals on salmon runs below Bonneville Dam is managed within the framework of applicable statutes and to the degree necessary to protect upstream migration of salmon.
5. Physiological stress and physical injury that may cause disease or increase susceptibility to pathogens during rearing or migration should be reduced during critical low flow periods (e.g., low water years) or poor passage conditions (e.g., at diversion dams or bypasses).

**Factor D: The inadequacy of existing regulatory mechanisms**

To determine that the ESU or DPS is recovered, any inadequacy of existing regulatory mechanisms that threatens its continued existence should be addressed to the degree necessary to support a viable ESU or DPS, as outlined below:

1. Sufficient resources, priorities, regulatory frameworks, and coordination mechanisms are established and/or maintained for effective enforcement of land and water use regulations that protect and restore habitats and for the effective management of fisheries.
2. Habitat conditions and watershed functions are protected through land-use planning that guides human population growth and development.
3. Habitat conditions and watershed function are protected through regulations that govern resource extraction such as timber harvest and gravel mining.
4. Habitat conditions and watershed functions are protected through land protection agreements as appropriate and where existing policy or regulations do not provide adequate protection.
5. Regulatory, control, and education measures to prevent additional exotic plant and animal species invasions are in place.

**Factor E: Other natural or human-made factors affecting its continued existence**

To determine that the ESU or DPS is recovered, other natural and human-made threats to its continued existence should be addressed as outlined below:

1. Hatchery programs are being operated in a manner that is consistent with individual watershed and region-wide recovery approaches, recognizing Federal obligations; appropriate criteria should be used for the integration, where appropriate, of hatchery populations and extant natural populations inhabiting watersheds where the hatchery fish return.
2. Hatcheries operate using appropriate ecological, genetic, and demographic risk containment measures for: (1) hatchery-origin adults returning to natural spawning areas, (2) release of hatchery juveniles, (3) handling of natural-origin adults at hatchery facilities, (4) withdrawal of water for hatchery use, (5) discharge of hatchery effluent, (6) maintenance of fish health during their propagation in the hatchery.
3. Mechanisms are in place to effectively continue monitoring the proportion of hatchery and wild spawners in the watershed.
4. Mechanisms are in place to reduce the incidence of, and impacts from, introduced, invasive, or exotic plant and animal species.
5. Nutrient enrichment programs should be evaluated to determine where additional nutrient inputs can provide significant benefits.

# 4 Current Status Assessment

In 2004, the W/LC TRT completed a population extinction risk evaluation of salmon and steelhead populations in the Willamette and LCR Basins, including White Salmon River populations (McElhany et al. 2004). During the evaluation, biologists ranked each population for absolute extinction risk on a scale of 0 to 4, with 0 = extirpation or nearly so, and 4 = very low extinction risk (McElhany et al. 2003). Each member of the W/LC TRT, based on the information available, ranked the VSP attributes such that the score for each attribute added up to 10, and then they provided an estimate of "data quality" based on their assessment of the overall amount of information available for each attribute (McElhany et al. 2004). Discussed below are the results of this evaluation.

## 4.1 Risk of Extinction: Willamette/Lower Columbia TRT

### White Salmon River Fall Chinook salmon

White Salmon River fall-run Chinook salmon received a weighted average score of 0.86, suggesting that the population is at a very high risk of extinction (Table 4-1). In their review, W/LC TRT members recognized the population's low total abundance, some team members commented that the population is extirpated from its historical range, except for 2 to 2.5-mile reach below Condit Dam, and that the overwhelming majority of fish observed in the river are strays from nearby hatcheries. Other members considered the observed adults as *de facto* population members (McElhany et al. 2004). Overall, most TRT members considered the in-river fall-run Chinook salmon population to be heavily influenced by hatchery strays, although some members included the Spring Creek NFH in their diversity evaluation as a potential source for re-establishing a native-run.

**Table 4-1. Evaluation scores for White Salmon fall-run Chinook salmon (McElhany et al. 2004)**

| *Attribute** | *0.00* | *1.00* | *2.00* | *3.00* | *4.00* | *Average* | *Data quality* |
|---|---|---|---|---|---|---|---|
| ***Productivity*** | 3.17 | 4.67 | 2.17 | 0.00 | 0.00 | 0.90 | 1.83 |
| ***Juvenile outmigrants*** | | | | NR | | | |
| ***Diversity*** | 2.00 | 3.33 | 3.83 | 0.83 | 0.00 | 1.35 | 2.00 |
| ***Habitat*** | 3.50 | 5.00 | 1.50 | 0.00 | 0.00 | 0.80 | 1.50 |
| ***Spatial Structure*** | 7.17 | 2.83 | 0.00 | 0.00 | 0.00 | 0.28 | 3.00 |

* W/LC TRT scores rated on a 0-4 scale: 0 = extirpated or nearly so, 1 = relatively high extinction risk, 3 = low extinction risk, and 4 = very low extinction risk. NR = not relevant

### White Salmon River Spring Chinook salmon

McElhany et al. (2004) gave the White Salmon spring-run Chinook salmon a weighted average extinction risk score of 0.07, indicating the population is extirpated (Table 4-2). The team concluded that the population is extirpated from construction and over 90 years of blocked passage at Condit Dam. Some members included observed spring-run-timed spawners at the base of Condit Dam, while others considered these fish as strays spawning in unsuitable habitat for spring-run Chinook salmon (McElhany et al. 2004).

**Table 4-2. Evaluation scores for White Salmon spring-run Chinook salmon (McElhany et al. 2004)**

| *Attribute** | *0.00* | *1.00* | *2.00* | *3.00* | *4.00* | *Average* | *Data quality* |
|---|---|---|---|---|---|---|---|
| ***Productivity*** | 9.33 | 0.67 | 0.00 | 0.00 | 0.00 | 0.07 | 1.33 |
| ***Juvenile outmigrants*** | 10.00 | NR | NR | NR | NR | NR | 4.00 |
| ***Diversity*** | 8.33 | 1.33 | 0.33 | 0.00 | 0.00 | 0.20 | 1.50 |
| ***Habitat*** | 10.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.50 |
| ***Habitat (w/o dams)*** | 3.75 | 3.50 | 2.75 | 0.00 | 0.00 | 0.90 | 1.50 |
| ***Spatial structure*** | 9.67 | 0.33 | 0.00 | 0.00 | 0.00 | 0.03 | 3.17 |

* W/LC TRT scores rated on a 0-4 scale: 0 = extirpated or nearly so, 1 = relatively high extinction risk, 3 = low extinction risk, and 4 = very low extinction risk. NR = not relevant

### White Salmon River coho salmon

White Salmon coho salmon received a weighted average extinction risk score of 0.39, indicating that the population is extirpated or nearly so (Table 4-3). TRT members, however, used a default score for no data, which assumes that fish may exist but are not monitored; other members noted that the White Salmon coho salmon population was probably extirpated following construction of Condit Dam, implying the default score might not be appropriate (McElhany et al. 2004). The TRT determined that hatchery introductions, the near absence of accessible spawning habitat, and the low probability of any successful natural reproduction suggest that most genetic diversity native to the White Salmon is extirpated and was replaced by hatchery introductions. In evaluating the habitat criterion, many TRT members included historical spawning habitat above the dam in their considerations (McElhany et al. 2004).

**Table 4-3. Evaluation scores for White Salmon coho salmon (McElhany et al. 2004)**

| **Attribute*** | **0.00** | **1.00** | **2.00** | **3.00** | **4.00** | **Average** | **Data quality** |
|---|---|---|---|---|---|---|---|
| Productivity | 5.00 | 5.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.17 |
| Juvenile outmigrants | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Diversity | 7.83 | 2.17 | 0.00 | 0.00 | 0.00 | 0.22 | 1.50 |
| Habitat | 5.33 | 3.67 | 1.00 | 0.00 | 0.00 | 0.57 | 2.00 |
| Spatial structure | 9.17 | 0.83 | 0.00 | 0.00 | 0.00 | 0.08 | 1.83 |

* W/LC TRT scores rated on a 0-4 scale: 0 = extirpated or nearly so, 1 = relatively high extinction risk, 3 = low extinction risk, and 4 = very low extinction risk.

### Upper Gorge Tributaries chum salmon

Upper Gorge Tributaries chum salmon, including those that occupied the White Salmon historically, received a weighted average extinction risk score of 0.18, indicating that the population is extirpated or nearly so (Table 4-4). Data are limited to Bonneville Dam passage counts, although many fish that ascend fall back to spawning areas below the dam. Fish technicians have recovered only a few carcasses above Bonneville Dam; no one has reported spawning aggregations, although biologist M. Weeber, (Weeber, M. personal communication, Oregon Department of Fish and Wildlife (ODFW), 2010), observed individual spawners in Eagle Creek, Oregon. The Bonneville Pool eliminated spawning habitat in both the mainstem and lower creek reaches, creating a series of disconnected spawning sites and culverts, and, stream modifications on the transit corridor on the Washington side of the CR may limit access for a few chum salmon that may be present. Low abundance for the species as a whole may also restrict population dispersal (McElhany et al. 2004).

**Table 4-4. Evaluation scores for upper Gorge chum salmon (McElhany et al. 2004).**

| Attribute* | 0.00 | 1.00 | 2.00 | 3.00 | 4.00 | Average | Data quality |
|---|---|---|---|---|---|---|---|
| Productivity | 9.50 | 0.50 | 0.00 | 0.00 | 0.00 | 0.05 | 1.00 |
| Juvenile outmigrants | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Diversity | 8.67 | 1.33 | 0.00 | 0.00 | 0.00 | 0.13 | 1.17 |
| Habitat | 6.67 | 2.67 | 0.50 | 0.17 | 0.00 | 0.42 | 1.83 |
| Spatial structure | 7.33 | 1.83 | 0.67 | 0.17 | 0.00 | 0.37 | 1.83 |

* W/LC TRT scores rated on a 0-4 scale: 0 = extirpated or nearly so, 1 = relatively high extinction risk, 3 = low extinction risk, and 4 = very low extinction risk.

## 4.2 Extinction Risk: Interior Columbia TRT

### White Salmon River Steelhead

Scientists consider the White Salmon River steelhead population functionally extirpated. The abundance of native summer and winter steelhead in the White Salmon River before 1919, when the loss of the fish ladder at Condit Dam blocked passage to upriver spawning and rearing grounds is unknown. However, some natural steelhead production in the reach below Condit Dam continued to occur (Bambrick et al. 2004). Some biologists believe that residual steelhead populations in the form of resident trout may contribute to anadromy in the watershed. *O. mykiss* from Rattlesnake Creek have been observed showing physiological changes consistent with smoltification, and fish have been detected outmigrating during the typical smolt migration period (B. Allen, personal communication, 2007). As further evidence in support of the retention of anadromous life history traits, a PIT-tagged *O. mykiss* was detected outmigrating from lower Rattlesnake Creek in March 2005, and was detected again in July 2006 moving up through the adult fish ladder at Bonneville Dam, possibly as a

one-salt steelhead (B. Allen, personal communication, 2007). Even with this observation, remnant genetic influences from the original White Salmon River steelhead population in fish spawning in the small section of the White Salmon River below Condit Dam is thought to be minor with natural production coming primarily from the large releases of out-of-basin hatchery stock.

Biologists generally believe that White Salmon River steelhead historically ranged from the mouth to RM 16.3 in the mainstem and into Buck, Spring, Indian, and Rattlesnake creeks (Figure 4-12) (ICTRT 2008). Some anecdotal historic records (WDF 1951), suggest that anadromous fish may have once ascended the White Salmon River as far as Trout Lake, RM 28.2. Most biologists, however, consider Big Brother Falls, RM 16.2, to be the upper limit of historical steelhead migration (NPCC 2004). This historical range provided approximately 33 to 40 miles of steelhead spawning and rearing habitat (NPCC 2004; Bambrick et al. 2004; Ecology 2007).

The ICTRT identified one MaSA, below Big Brother Falls, within the White Salmon watershed based on its historical intrinsic potential analysis. The ICTRT defines a MaSA as a system of one or more branches that contains sufficient habitat to support at least 500 spawners. The ICTRT does not consider any population fewer than 500 spawners to be viable, regardless of its intrinsic productivity.

Figure 4-1 shows the intrinsic habitat potential and MaSA for the White Salmon River summer/winter steelhead populations as identified by the ICTRT in their 2008 analysis (ICTRT 2008). Intrinsic potential is the estimated relative suitability of a habitat for spawning and rearing of anadromous salmonids species under historical conditions inferred from stream characteristics including channel size, gradient, and valley width.

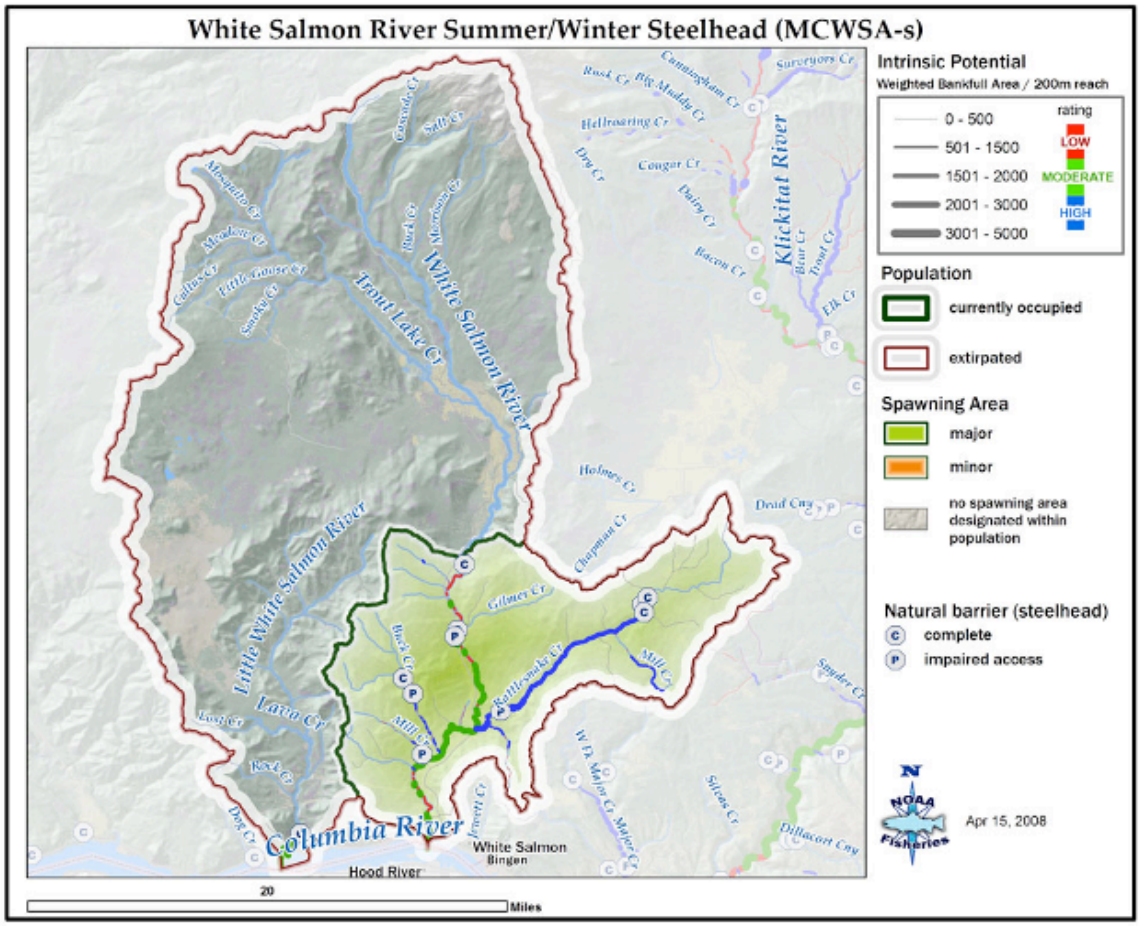


**Figure 4-1. Intrinsic habitat potential and Major Spawning Area for the White Salmon River summer/winter steelhead (ICTRT 2008)**

# 5 Limiting Factors and Threats

Scientists generally describe the reasons for a species' decline in terms of limiting factors and threats. Analysis of limiting factors and threats across the entire species' life cycle forms the basis for designing recovery strategies and actions. NMFS defines limiting factors as the biological and physical conditions limiting DPS and population status (e.g., elevated water temperature), and defines threats as those human activities or naturally induced actions that cause the limiting factors (e.g., removal of riparian vegetation for agricultural or residential purposes, which causes loss of shade and, consequently, elevated water temperature).

For salmon and steelhead, survival to reproduce depends on a complex, interacting system of environmental conditions, with different conditions needed for each life stage. Optimal water temperature, for example, varies (within limits) for adult migration versus egg incubation or juvenile rearing. Because of this complexity, in many cases, scientists have a poor understanding of the actual limiting factors.

The list of limiting factors for the White Salmon River salmon and steelhead populations, as for the other populations that make up the LCR salmon ESUs and the MCR steelhead DPS addressed in this recovery plan, is based on a substantial body of research on salmonids, local field data and field observations, and the considered opinions of regional experts. These are implicitly hypothetical statements, made with the expectation that by taking action in the face of some degree of scientific uncertainty, then monitoring the results, continuing to conduct research as a high priority, and adapting our management actions in response, the state of our knowledge will improve and so will fish survival, although not necessarily in a directly parallel process.

Until recently, the primary factor limiting production of all White Salmon species was the presence of Condit Dam. PacifiCorp breached the dam in October 2011, and has removed the structure. Now that the dam no longer serves as a barrier to upstream migration, the primary factor affecting recovery in the White Salmon River watershed is the lack of native stocks. Spring Chinook salmon, coho, chum salmon, and steelhead populations are either extirpated or functionally extirpated (Good et al. 2005, ICTRT 2007b, Ford et al. 2011). The development of local populations will necessitate natural re-colonization or require the introduction of stocks from other basins, but may be limited by the quality of habitat within the watershed.

Salmon and steelhead have not occupied the habitat upstream of the dam for decades. An abundance of unoccupied habitat is present in the basin. Therefore, habitat quality upstream of the former dam is not currently limiting the populations. Fall Chinook salmon and some strays of other species utilize the lower river below the former Condit Dam. The numbers of fall Chinook salmon spawners increased from low levels in the early 2000s (WDFW 2002) to an average of 2,750 for the 2007-08 period (Roler 2009). The majority of the fall Chinook salmon, spawning in the lower river, were assumed to be strays from Spring Creek NFH. The marking of all of the production at Spring Creek NFH has shown that the escapement in recent years has been overwhelmingly from natural-origin fall Chinook salmon (Roler 2011). Prior to breaching of the dam, the habitat in the lower river may have been limiting Chinook salmon production in the years of high abundance.

In the future, some of the species that historically occupied the watershed may slowly begin to occupy upstream habitat through natural re-colonization/straying. More direct stocking may also occur to facilitate the rate of population growth. As the populations recover, some factor related to in-river habitat, quality may eventually become the factor limiting salmonid production. To a certain degree, this will depend upon the species that come to occupy that habitat and also on the degree that the various natural waterfalls in the basin end up restricting dispersion of the species.

When the dam was breached, the reservoir drained quickly. Biologists have not yet had the opportunity to evaluate the current condition of habitat downstream of the dam, but they anticipate large amounts of sediment entering the lower river and moving into the Columbia River. They cannot predict, with any certainty, other habitat conditions after removal; however, the reduction of habitat carrying capacity of the habitat is likely to persist for some unknown period of time. Habitat downstream of the dam may limit population production in the lower river until that habitat recovers from the effects of the removal of the dam, though redds were observed in the lower river in 2012 (R. Engle, USFWS, personnel communication December 2012).

The discussion below further describes what biologists currently know about the condition of the basin's habitat. Numerous studies completed since 2002, including the applicable results of the EDT run completed in 2004 (Allen and Connolly 2005), form the basis of this habitat discussion. In that spirit, this chapter describes potential factors that may limit future anadromous salmon and steelhead populations in the White Salmon River watershed. Chapter 5 is organized as follows:

- Section 5.1 addresses the migration barrier at Condit Dam.
- Section 5.2 identifies freshwater life cycle factors.
- Section 5.3 describes effects on the populations from hatchery production and releases.
- Section 5.4 discusses impacts from harvest.
- Section 5.5 identifies effects from the CR hydrosystem.
- Section 5.6 discusses effects of predation.
- Section 5.7 discusses ocean effects.
- Section 5.8 discusses climate change.
- Section 5.9 discusses other large-scale threats.

## 5.1 Blocked Migration and Impaired Passage

The single greatest factor limiting salmon and steelhead populations in the White Salmon River watershed was the migration barrier at Condit Dam. Only a small percentage of the historical anadromous spawning and rearing areas was accessible. Table 5-1 presents the current or pre-Condit Dam removal and historical distribution (post Bonneville Dam) within the White Salmon River watershed based on the assumptions built into the EDT model. Note

that as an artifact of the EDT model, it defined fall and spring Chinook salmon spawning habitat with no overlap. As a result, the fall Chinook salmon habitat was reduced to cover an area less than what biologists generally believe to be historically accessible. Biologists have considered fall Chinook salmon habitat to have historically extended up to Husum Falls at RM 7.6, which may overlap with possible spring Chinook salmon spawning habitat between Condit Dam and Husum Falls. Chum salmon is the only species that would have access to all of its remaining historical range with the dam in place.

Table 5-2 summarizes primary limiting factors for LCR fall Chinook salmon. Table 5-3 summarizes additional limiting factors affecting anadromous fish in the White Salmon River Basin. Described below are these limiting factors.

**Table 5-1. River miles of salmon and steelhead habitat above and below Condit Dam (NPCC 2004).**

| *Species* | *Historical Distribution* | *Current Distribution* | *% of Historical Access* | *Comments* |
|---|---|---|---|---|
| *Chum salmon* | 1.2 miles | 1.2 miles | 20% | 80 percent of spawning area flooded by Bonneville Dam |
| *Fall Chinook salmon* | 3.6 miles | 3.4 miles | 94% | 6 percent of spawning area above Condit Dam |
| *Spring Chinook salmon* | 12.8 miles | 0 miles | 0% | All of spawning area above Condit Dam |
| *Coho salmon* | 21.1 miles | 3.4 miles | 16% | Majority of spawning area above Condit Dam |
| *Steelhead* | 32.9 miles | 3.4 miles | 10% | Majority of spawning area above Condit Dam |

## 5.2 Freshwater Habitat

### 5.2.1 Lower White Salmon River Habitat Below Condit Dam

Prior to removal, operations at Condit Dam had reduced the rearing potential in the bypass reach downstream of the dam because minimum flows were 15 cfs, which was only a small percentage of the natural low flows of approximately 626 cfs (United States Geographic Survey (USGS) 2010). Power peaking associated with dam operation caused further diel flow variation, which has led to dewatering, stranding, and an increase in bioenergetic losses because of movements associated with daily flow changes.

The transport of rock and sediment, as well as nutrients, cold water and large wood down the White Salmon River stopped at Northwestern Lake. As a result, coarse material tends to dominate the reach downstream of the dam. Historically, this reach likely had more gravel,

cobble, and large wood which salmon and steelhead used as spawning habitat, than is currently present.

The removal of Condit Dam has restored normative flows in the reach. Sediment and woody material transport is also being re-established. During the years after dam removal, flows will transport fine sediment out of the previous reservoir area downstream to the CR. These sediments are likely to affect the quality of spawning habitat in the reach downstream of the dam until the river re-establishes a stable channel and the banks of the new channel also become relatively stable. The reduced habitat quality may decrease the numbers of fall Chinook salmon (and other species that stray into the lower river) that the river can support for an unknown number of years.

Steelheads use the lower reach of the White Salmon River and the area at the mouth of the White Salmon River. Other species migrating to rivers upstream of the White Salmon River use the river as a cool water refuge in the summer and also as temporary overwintering habitat (High et al. 2006; Keefer et al. 2008). By filling in rearing area and holding pools, the sediment released from behind the dam may alter this cool water refuge area for upstream migrants. The return of downstream wood transport may help to eventually deposit wood that helps to scour pools, sort sediments and create holding habitat.

### 5.2.2 Habitat Upstream of Condit Dam

#### Flow Regimes

A watershed analysis conducted by the USFS in the upper White Salmon River indicated that, based on past management activities, portions of the upper White Salmon River may be subject to increased peak flow events (USFS 1998). Tributary reaches of the White Salmon generally have more volatile flows than the mainstem White Salmon. Road building, removal of trees from riparian areas, clearing of forests and agricultural lands, loss of wetlands, and other impacts on ecosystem function may have modified the intensity of flows in some tributary reaches.

#### Channel Structure, Riparian Condition, and Floodplain Connectivity

Some stream reaches in the tributaries have few deep pools and little instream wood (Allen et al 2006a, 2006b; Morris 2004). Substrate in Rattlesnake Creek has a low percentage of ‘fines’ and abundance of spawning sized material (Morris 2003). No additional data representing habitat quality in the mainstem White Salmon River are available to date.

Both timber harvest and fires have impacted forested lands within the lower reaches of the watershed. Biologists consider 72 percent of riparian areas within the upper White Salmon to be late successional, as compared with 38 percent for the entire basin (USFS 2002). Small red alder tends to dominate riparian areas along Rattlesnake and Buck Creeks; conifers in the riparian area are sparse (Allen et al. 2006a, 2006b).

Roads can affect salmonid habitat by reducing natural infiltration and increasing hydro-confinement, leading to altered flow regimes, peak flows, and increased delivery of fine sediment to streams. The magnitude of effect as measured by road density is dependent upon

the number of roads, the locations of roads, the surfacing used, traffic levels, and mid-slope engineering of the road (Dubé et al. 2004).

Researchers calculated road densities (road miles/square-mile) in the upper, middle, and lower White Salmon River at 3.7 miles per square mile (2.3 kilometers per square km), 3.1 miles per square mile (1.9 kilometers per square kilometer), and 4.0 miles per square mile (2.5 km per square km), respectively. Tributary road density in the upper White Salmon ranged from 0.2 to 4.4 miles per square mile (0.1 to 2.7 km per square km) (USFWS 2002). Rattlesnake Creek has a density of 3.54 miles per square mile (2.2 km per square km) and Buck Creek a density of 5.05 miles per square mile (3.1 km per square km) (Allen and Connolly 2005). Analyses of the effects of roads on sediment inputs or stream flow have been limited to the headwaters of the mainstem (USFS 2002) and the headwaters of Rattlesnake Creek (Panakanic Watershed Analysis, http://fortress.wa.gov/dnr/forestpractices/wsasmt.cgi?wsaval=acme (accessed April 11, 2012). The Forest Service assessment identified roads that needed addressing. The upper Rattlesnake assessment found that roads were not contributing high amounts of sediment.

After the dam decommissioning efforts are completed, fine sediment will likely dominate habitat in the area previously occupied by the reservoir until such time as the fine materials deposited behind the dam are transported out of the reach, a new channel becomes established, and banks stabilize. Riparian seeding and tree planting, described in PacifiCorp's Re-vegetation and Wetlands Management Plan (PacifiCorp Energy 2010), will address the lack of riparian vegetation in the inundated area. Wood abundance may be high because the reservoir stopped downstream transport of woody debris since 1919; actual abundance will depend on the amount of wood transported into the reservoir and the decay rate of that wood.

### Water Quality

Water temperature and dissolved oxygen levels in the mainstem White Salmon River are at or near optimum levels for salmonids (White and Plumb 2004). Maximum temperature within the expected anadromous range meets Washington state water quality standards with the exception of Rattlesnake Creek which approaches lethal temperatures in some locations in some years (White and Plumb 2004; White and Plumb 2005; White and Cochrane 2005, Connolly 2003; Morris 2005). Phosphorus and nitrate/nitrite in the basin (mainstem and tributaries) is very high. Phosphorus levels tend to be roughly twice the recommended EPA standard for creeks and streams and nitrate/nitrite is as much as two orders of magnitude higher that the EPA recommended standard (White and Plumb2004, 2005; White and Cochrane 2005, EPA 2000).

There are currently several segments of the mainstem White Salmon and tributaries listed as impaired waterways, 303(d) listings, by the Washington State Department of Ecology, although some of the data on which the listings are based needs updating. Ecology lists individual reaches on Gilmer Creek, Rattlesnake Creek, the mainstem White Salmon, and Trout Lake Ditch as Category 5 (water quality impaired) for fecal coliform. Temperature impairments have led to the Category 5 listing of reaches on Indian and Rattlesnake creeks http://www.ecy.wa.gov/programs/wq/303d/2008/index.html (accessed April 11, 2012).

## 5.3 Hatchery Production and Releases

Discussed below are effects of hatchery production and releases on White Salmon River salmon and steelhead populations.

### Chinook salmon

Tule fall Chinook salmon from Spring Creek NFH contribute to natural production of fall Chinook salmon in the White Salmon River. Most of the fish spawning naturally in the White Salmon River were assumed to be hatchery-origin tule fall Chinook salmon based on CWT recoveries. Spring Creek NFH began marking all of its hatchery production and as a result, recent spawning ground surveys have shown that the majority of the tule fall Chinook salmon returning to the White Salmon River are of natural origin (Roler 2011). Spring Creek NFH tule fall Chinook salmon originally derive from White Salmon tule fall Chinook salmon and biologists and recovery planners anticipate that Spring Creek NFH tule fall Chinook salmon may be used to supplement natural production in the future. Smith and Engle (2011) collected genetic samples from juvenile salmon emigrated from the White Salmon River and determined that the naturally produced fall Chinook salmon juveniles grouped with Spring Creek NFH tules when compared to other LCR tule fall Chinook salmon populations and stray URB fall Chinook salmon.

Stray URB hatchery fall Chinook salmon may be affecting the productivity of the tule fall Chinook salmon in the White Salmon River. These URB fall Chinook salmon are strays from releases at the LWS NFH and other releases in the Bonneville Pool. Through redd superimposition, URB fall Chinook salmon can adversely affect tule fall Chinook salmon: Peak spawning time for URB fall Chinook salmon is in late October and into November after tule fall Chinook salmon spawning has been completed. Since habitat has been very limited in the White Salmon River, URB fall Chinook salmon that spawn on top of tule fall Chinook salmon redds can decrease the productivity of the White Salmon River population. The LWS NFH is taking measures to decrease the number of stray URB fall Chinook salmon. Recent escapement data for the White Salmon River has shown a decrease in the abundance of URB fall Chinook salmon spawners, but in some years, their abundance exceeds that of tule fall Chinook salmon (Roler 2011). If these measures are unsuccessful in reducing the number of stray URB fall Chinook salmon to acceptable levels, the hatchery will implement other actions.

Biologists do not know the actual stray rate of Spring Creek NFH tule fall Chinook salmon into local tributaries, but these Spring Creek hatchery fish do contribute to naturally spawning tule fall Chinook salmon in upper gorge tributaries, including the White Salmon River. The exact proportion of these hatchery fish on the spawning grounds could not be determined because only a small number of the hatchery's fish were marked. The estimated number of tule fall Chinook salmon spawners has increased in recent years peaking in 2003 with 1,575 being observed in the Wind River, 12,471 in the White Salmon River, and 10,686 in the Klickitat River (Jenkins, 2006; Roler 2009). All recent production at Spring Creek NFH fall Chinook salmon have been externally marked allowing for differentiation between natural-origin and hatchery fall Chinook salmon in the White Salmon River. All age-classes of the hatchery tule fall Chinook salmon returning to Spring Creek NFH were marked in 2010, and escapement to the White Salmon River was estimated to be composed of 1,142

natural-origin and 558 hatchery-origin tule fall Chinook salmon adults (Roler 2011). Smolt-to-adult survival rates averaged 0.136 percent for the 1991-95 brood years (Spring Creek NFH Hatchery Genetic Management Plan (HGMP) 2002). The total exploitation rate for the hatchery program was as high as 75.3 percent for the 1982-89 brood years. An estimate for brood years 1990-93 has the total exploitation rate at 67 percent, with nearly half of the impacts occurring in the CR, primarily in the Zone 6 area above Bonneville Dam (Spring Creek NFH HGMP 2002).

Hatchery-produced spring Chinook salmon are not released into the White Salmon River Basin though strays from the LWS NFH and other programs were recovered at a weir on the White Salmon River in 2009 (Engle et al. 2010).

### Coho salmon

Hatchery biologists found that coho salmon from the LWS NFH had strayed into the White Salmon watershed prior to the closure of the program in 2004. Biologists consider these strays and others from releases further upstream in the CR to be the likely source of naturally spawning coho salmon in the White Salmon River.

### Steelhead

Until 2010, fisheries managers released summer and winter steelhead from Skamania broodstock into the White Salmon River below Condit Dam to support tribal and recreational fisheries. Technicians marked all hatchery fish to allow for selective fisheries. These releases may limit the diversity of any naturally produced winter steelhead in the basin. However, the primary constraint on summer and winter steelhead in the White Salmon River has been the limited spawning and rearing habitat. Further, biologists do not believe Skamania stock steelhead are reproductively successful when spawning naturally; thus, adverse effects on natural populations may be limited. The hatchery terminated releases of these hatchery fish as of 2010 and biologists expect any potential impacts associated with these releases within the White Salmon will diminish after 2011. There may also be significant straying of migrating hatchery fish from other basins into the White Salmon seeking a cold water refugia (High et al. 2006, Keefer et al. 2008). These strays may originate from different DPSs including the Snake River Basin. While some may contribute to rebuilding the population, other strays may have a negative impact.

## 5.4 Harvest

Harvest currently does not limit the abundance or the diversity of White Salmon River steelhead, and spring Chinook salmon, coho salmon, and chum salmon, populations. NMFS considers all of these populations extirpated or functionally extirpated (Good et al. 2005; ICTRT 2007b; Ford et al. 2011). Any coho, chum, spring Chinook salmon, and most steelhead found in the White Salmon River are strays from other basins. In the White Salmon River, non-tribal coho salmon and steelhead fisheries are selective for marked hatchery fish, requiring the release of unmarked salmon and steelhead. Regulations prohibit retention of fall Chinook salmon in the White Salmon River from October 1 to December 31.

### Fall Chinook salmon

Ocean fisheries off the coasts of Oregon, Washington, and British Columbia catch LCR fall-run (tule) Chinook salmon populations (NMFS 2008c). Total exploitation rates were generally higher through 1993 (averaging 69 percent), lower from 1994 to 1999 (averaging 34 percent), then increasing since 2000 (averaging 49 percent). From 2002 to 2006, regulators limited fisheries to a 49 percent exploitation rate. Total exploitation rates have been higher in some years but have averaged 49 percent from 2002 to 2006. The average exploitation rates for non-treaty fisheries in the CR for these same periods were 16 percent, 8 percent and 9 percent respectively. Tribal fisheries have a higher harvest rate on the Bonneville Pool tule populations, including the White Salmon River population (NPCC 2004; NMFS 2000).

For the last several years, NOAA Fisheries has limited Pacific Fisheries Management Council (Council) and in-river fisheries by specifying a total exploitation rate limit. From 2002 to 2006, the limit was 49 percent. The Council reduced the exploitation rate to 42 percent in 2007. NOAA Fisheries' guidance to the Council for 2008 was that Council fisheries should be managed such that the total exploitation rate on LCR Chinook salmon tule populations, from all fisheries does not exceed 41 percent. For 2009 and thereafter, NOAA Fisheries has set a total exploitation rate limit for tule Chinook salmon through their annual guidance letter to the Council. The Council's Salmon Forest Management Plan (FMP) requires NOAA Fisheries to provide such guidance. Fisheries subject to the 2008 *U.S. v. Oregon* Agreement that are part of the set of Prospective Actions must be managed subject to the overall exploitation rate limit as proposed in 2008 and have been since 1999 (NMFS 2008c). Biologists believe that tribal fisheries do not have a significant impact on the entire LCR tule fall Chinook salmon run, but do have a higher harvest rate on the Bonneville Pool tule populations, including the White Salmon River (NPCC 2004; NMFS 2000). Under the *U.S. v. Oregon* Agreement, there are a number of escapement and management objectives that limit the harvest of fall Chinook salmon in fisheries that would impact White Salmon River fall Chinook salmon, for example, a minimum escapement goal of 7,000 adults (4,000 females) to meet broodstock needs at Spring Creek NFH can restrain ocean, lower river mainstem, and above Bonneville Dam treaty fisheries (NMFS 2008c).

Tributary fisheries minimally impact tule fall Chinook salmon. The White Salmon River tributary fishery accounts for less than one percent of the total run-size of LCR fall Chinook salmon and less than 4 percent of the White Salmon River tule fall Chinook salmon (NMFS 2008c). Currently, Washington fisheries regulations allow fall Chinook salmon retention in the lower White Salmon River from July 1 to March 31 annually, but close the river to the retention of Chinook salmon ½ mile upstream from the Highway 14 bridge from October 1 to December 31 to protect spawning salmon (WDFW 2009). Catch record cards are the basis for the estimated total recreational Chinook salmon catch in the White Salmon River. These data can contain recording errors and fish misidentification, along with dip-in fish destined for upriver systems. The exploitation rate of White Salmon River tule fall Chinook salmon during WDFW-regulated fisheries in the White Salmon River is less than 5 percent of the terminal run. Biologists estimate the terminal run-size based on the annual catch rate and spawning escapement estimate data collected since 1995 (NPCC 2004). The average annual catch of wild tule fall Chinook salmon is approximately 30 fish and the average annual escapement estimate is 461, therefore, the average annual terminal run of White Salmon

River tule fall Chinook salmon is approximately 491 fish. Biologists extrapolate total run-size of the White Salmon River tule fall Chinook salmon and total fisheries impact from these data. Using the estimated annual terminal run-size and estimated annual exploitation from ocean and CR mainstem fisheries, the estimated average total run-size of White Salmon River tule fall Chinook salmon is 784 fish (NPCC 2004). The total number of fall Chinook salmon spawners (natural-origin and hatchery) has increased from low levels in the early 2000s (USFWS 2004) to an average of 2,750 for the 1998-2007 period (Roler 2009). The sport harvest has remained at roughly 30 adult fall Chinook salmon (Kraig and Smith 2008). Therefore, in recent years the proportion of the total escapement caught in the fishery has remained small.

### Spring Chinook salmon

If the White Salmon River produced spring Chinook salmon, they would contribute to lower Columbia mainstem fisheries and treaty fisheries in the Bonneville Pool. Spring Chinook salmon originating from above Bonneville Dam do not contribute to ocean fisheries compared to other LCR spring Chinook salmon populations (NMFS 2008c). Fishery managers would deal with spring Chinook salmon originating from the White Salmon River as part of the upriver spring and Snake River summer Chinook salmon group. This group includes all natural and hatchery produced spring Chinook salmon originating from the CR and its tributaries above Bonneville Dam (NMFS 2008c). The abundance of this group and the status of natural-origin spring Chinook salmon from the Snake River and upper CR is the basis for establishing harvest rates for both lower river commercial and recreational fisheries and tribal treaty fisheries above Bonneville Dam. The harvest rate for this group averaged 14.5 percent from 1999 to 2008, but the actual harvest rate for prospective White Salmon spring Chinook salmon would be less because they are not exposed to the full Zone 6 (above Bonneville) treaty fishery (ODFW and WDFW 2009). Tributary sport regulations for the White Salmon River require the release of unmarked Chinook salmon from April 1 to June 30 protecting natural-origin spring Chinook salmon that may enter the White Salmon River (WDFW 2009).

### Coho salmon

NMFS considers White Salmon coho salmon extinct and therefore allows no fisheries targeting coho salmon in the White Salmon River (Good et al. 2005). Stray hatchery coho salmon can be retained and all wild coho salmon must be released in fisheries downstream of the location of Condit Dam from July 1 to March 31 (WDFW 2009) LCR coho salmon are caught in both ocean and in-river fisheries. Until 1993 the exploitation rates of LCR coho salmon have been very high, contributing to their decline (NMFS 2008c). The combined ocean and in-river exploitation rates for LCR coho salmon averaged 91 percent through 1983, averaged 69 percent from 1984-1993, and decreased to an average of 16.7 percent from 1994-2007 (NMFS 2008c). The exploitation of hatchery coho salmon has remained approximately 50 percent through the use of selective fisheries.

The Pacific Fishery Management Council in accordance with the 2008 *U.S. v. Oregon* Agreement and related biological opinions regulates LCR coho salmon harvest, which is subject to a total exploitation rate limit for the combined ocean and in-river fisheries. Previously, ocean regulators used Oregon Coast natural coho salmon as a surrogate for

estimating ocean fisheries impacts to LCR coho salmon. In 2006, largely as a consequence of increased attention resulting from its listing, the methods for assessing harvest in ocean fisheries changed so that they were more specific to LCR coho salmon (NMFS 2008c).

Each year, harvest managers in the CR will set coho salmon fishing regulations, after accounting for anticipated ocean harvest, so as not to exceed the total exploitation rate limit. In 2008, the total exploitation rate limit was 8 percent based on the year specific circumstances. For 2009 and thereafter, NOAA Fisheries will set a total exploitation rate limit for LCR coho salmon through their annual guidance letter to the Council. Fisheries subject to the 2008 *U.S. v. Oregon* Agreement that are part of the set of Prospective Actions must be managed subject to the overall exploitation rate limit as proposed in 2008 and as they have been since 1999. Under the *U.S. v. Oregon* Management Agreement (NMFS 2008c) these non-treaty fisheries do not exceed the 50 percent catch sharing objective for coho salmon destined for above Bonneville Dam.

### Chum salmon

In the first half of the 20th century there was a substantial commercial chum salmon fishery with a harvest rate of more than 500,000 chum salmons in some years (Myers et al. 2006). Harvest of chum salmon in the CR is limited to indirect fishery mortality. Regulators closed or drastically minimized commercial chum salmon fisheries in the 1950s due to severe population declines. Currently, there are no recreational or commercial fisheries in the CR. The number of chum salmon landed as take incidental to lower river commercial gill net fisheries has been fewer than 50 fish in each of the last five years. Harvest impacts to chum salmon from CR commercial and recreational fisheries are constantly below 5 percent and since 1998 have averaged 1.6 percent. Biologists assume ocean fishing mortality on CR chum salmon to be zero. Regulations prohibit retention of chum salmon in the White Salmon River.

### Middle Columbia River steelhead

NMFS considers White Salmon River steelhead functionally extirpated (ICTRT 2007b). Any future White Salmon River produced steelhead would have similar fishery impacts as biologists have observed for steelhead destined for the other MCR Basins in Bonneville Pool. Various fisheries can catch these steelhead as they migrate through the CR and Pacific Ocean. These fisheries are discussed briefly below.

#### *Ocean Fisheries*

Ocean fisheries rarely catch steelhead; therefore, biologists do not consider these fisheries a significant source of mortality to MCR steelhead (NMFS 2000). Biologists assume ocean fishing mortality on MCR steelhead to be zero.

#### *Columbia River Mainstem Non-Tribal Fisheries*

There has been no direct freshwater non-tribal harvest on wild steelhead from the MCR steelhead DPS since 1992, when the last wild fish catch-and-release regulations on these populations became effective. Therefore, all current non-tribal harvest impacts on Mid-Columbia DPS steelhead are due to incidental by-catch in commercial or recreational fisheries that target hatchery steelhead or other species. Monitoring these impacts is

complex. Released fish experience a mortality rate, possibly delayed and difficult to measure, that is highly variable and depends on what gear is used, how the fish are caught by the gear, how the fish are handled during capture and release, and environmental conditions. Biologists estimate release mortality to be very low (below one percent of encounters (NMFS 2008c)), with an unknown range of error. Fish technicians monitor recreational fisheries by conducting creel surveys, interviewing anglers about their catch, gear, and wild steelhead releases. Biologists estimate the total recreational impact on winter and summer steelhead as they move through the mainstem to the tributaries to be less than 2.5 percent (ODFW 2008).

There are three stocks of summer steelhead used for management of treaty and non-treaty mainstem fisheries, including the LCR Skamania stock, upriver A-run stock, and upriver B-run stock. All MCR steelhead populations are designated A-run, with two populations being winter-run. In NOAA's Biological Opinion for the 2008-2017 *U.S. v. Oregon* Fisheries Agreement, the wild MCR Steelhead DPS in the non-treaty winter, spring, and summer mainstem fisheries are subject to a 2 percent harvest rate limit (NMFS 2008c). Non-treaty fall fisheries are also limited to a 2 percent harvest rate limit for A-run summer steelhead. The total annual harvest rate limit for A-run steelhead in non-treaty fisheries is 4 percent and 2 percent for the summer-run and winter-run of the MCR steelhead DPS, respectively. The expected harvest impacts from non-treaty fisheries are less than the limits proposed in the *U.S. v. Oregon* Fisheries Agreement. The yearly incidental catch of A-run steelhead in non-treaty fisheries has averaged 1.6 percent since 1999; co-managers do not expect to the incidental catch rate to change over the course of the Agreement (NMFS 2008c).

#### *Treaty Indian Fisheries*

Tribal fishers in Zone 6 of the Columbia mainstem (between Bonneville Dam and McNary Dam) continue to retain wild steelhead for commercial sale or for personal use. The *U.S. v. Oregon* Fisheries Agreement does not establish specific harvest rate limits for tribal fisheries on steelhead during the spring or summer seasons that extend through July 31. Reported steelhead catch in Zone 6 winter and spring fisheries for 2003 to 2005 ranged from 0.7 percent to 7.9 percent of the winter steelhead run over Bonneville Dam. In 2004, reported and estimated non-reported steelhead catch together amounted to 4.8 percent of the run at Bonneville, with an unknown range of error (ODFW 2008).

Harvest restrictions for B-run steelhead and upper CR bright fall Chinook salmon limit tribal fishery impacts on MCR steelhead (NMFS 2008b). The harvest rate on MCR summer-run steelhead in spring, summer, and fall Zone 6 tribal fisheries combined averaged 11.7 percent since 1985 and 6.64 percent since 1998 (NMFS 2008b, Table 8.8.5.5-1). Co-managers expect the impacts resulting from the tribal fisheries to be similar to the 1998-2006 average of 6.64 percent. The harvest rate is mostly for populations that pass more dams in Zone 6 than the White Salmon steelhead population, which passes only one Zone 6 dam. White Salmon steelheads are therefore subject to fewer non-Native American and tribal treaty fisheries and experience a harvest rate estimated to be less than 10 percent.

#### *White Salmon River Fisheries*

The White Salmon River was open year-round for marked hatchery steelhead up to the Powerhouse outfall. After dam breaching, the area open to steelhead fisheries is the lower three miles of the mainstem river, and also upriver as far as Husum. This fishery harvests

marked Skamania hatchery steelhead released in the basin as juveniles and out-of-basin steelhead that dip-in to the White Salmon River when seeking cooler water temperatures in the summer. According to catch card data available for the 2002-03 return year, fisheries harvested 3,135 marked summer steelhead and 133-marked winter steelhead (WDFW 2008). Non-tribal fisheries for Chinook salmon and coho salmon are open in the lower White Salmon River all year and require the release of unmarked Chinook salmon and coho salmon by non-tribal fishers.

## 5.5 Federal Columbia River Hydrosystem

Hydropower system construction and operation (flow regulation) in the CR Basin has been a major cause of changes in the CR and estuary from historical conditions.

Within the White Salmon watershed, creation of the Bonneville Dam pool on the mainstem CR affected steelhead and salmon by effectively inundating the lower 0.96 miles of the habitat. This resulted in the loss of riparian, spawning, and rearing habitat and increased predation by native and non-native fish in the lower river. The effects are greatest on White Salmon chum salmon, since the dam inundated all but 0.24 miles of their original habitat. A lack of historical data inhibits quantitative evaluation of the impacts of Bonneville pool inundation on native fish, plant, and wildlife species.

Dams altered conditions within much of the mainstem Columbia and Snake Rivers compared to historic conditions. The development of hydropower and water storage projects within the CR Basin resulted in the inundation of many mainstem spawning and shallow-water rearing areas (e.g., loss of spawning gravels and access to spawning and rearing areas); altered water quality (e.g., reduced spring turbidity levels), water quantity (e.g., seasonal changes in flows and consumptive losses resulting from use of stored water for agricultural, industrial, or municipal purposes), water temperature (e.g., including generally warmer minimum winter temperatures and cooler maximum summer temperatures), water velocity (e.g., reduced spring flows and increased cross-sectional areas of the river channel), food (e.g., alteration of food webs, including the type and availability of prey species), and safe passage (e.g., increased mortality rates of migrating juveniles) (Williams et. al 2005; Ferguson et. al 2005).

Model studies indicate that the hydrosystem and reduced river flows caused by climate change together have decreased the delivery of suspended particulate matter to the lower river and estuary by about 40 percent (as measured at Vancouver, Washington) and have reduced fine sediment transport by 50 percent or more (Bottom et al. 2005). Overbank flow events, important to habitat diversity, have become rare, in part because flow management and irrigation withdrawals prevent high flows and in part because diking and revetments have increased the "bankfull" flow level (from about 18,000 to 24,000 m3/s). The dynamics of estuarine habitat have changed in other ways relative to flow. The availability of shallow (between 10 cm and 2 m depth), low-velocity (less than 30 cm/s) habitat now appears to decrease at a steeper rate with increasing flow than during the 1880s, and the absorption capacity of the estuary appears to have declined.

The CR Estuary Module, at http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Estuary-Module.cfm (accessed April 11, 2012), provides more information on factors that limit viability of LCR Chinook salmon and coho salmon, CR chum salmon, and MCR steelhead in the CR Estuary.

### 5.5.1 Hydro Project Impacts on Outmigrating Smolts

As anadromous juvenile salmonids migrate from freshwater rearing habitats to the ocean, they are vulnerable to a host of factors that affect their survival. Scientists have conducted many studies in recent years to determine both the direct effects associated with project passage (e.g., instantaneous mortality, injury, loss of equilibrium, reservoir and tailrace predation) and indirect effects (e.g., vulnerability to predation in the estuary or plume, disease, and physiological stress), which contribute to the total mortality of seaward migrating salmonids (Counihan et al. 2005).

White Salmon River salmonids must pass only Bonneville Dam on their way to and from the Pacific Ocean. The 2008 Federal Columbia River Power System (FCRPS) Biological Opinion's Reasonable and Prudent Alternative (RPA) requires a 10-year program of configuration improvements at the dam including the installation of turbines with minimum gap runners at Powerhouse 1 and increased guidance into the juvenile bypass systems at both powerhouses (NMFS 2008b). BPA will continue and further increase the pike minnow sport fishery incentive program, removing more of these predators from Bonneville pool. Upon implementation of these changes, juvenile survival from the mouth of the White Salmon to below Bonneville Dam is expected to be 95.5 percent for Chinook salmon, coho and chum salmon and 90.8 percent for steelhead (NMFS 2008b, Table 14.3 of the Incidental Take Statement).

### 5.5.2 Hydro Project Impacts on Migrating Adults

#### Passage Survival

Fish returning to the White Salmon watershed must pass Bonneville Dam and Reservoir. Prospective actions under the 2008 FCRPS Biological Opinion's RPA are expected to maintain the current high survival rates of 98.6 percent for spring-run Chinook salmon, 98.5 percent for steelhead, and 96.9 percent for fall-run Chinook salmon, coho, and chum salmon (NMFS 2008b, Table 14.1 of the Incidental Take Statement). Sea lions take about 22 percent of adult winter steelhead and 8.5 percent of adult spring Chinook salmon in the tailrace of Bonneville Dam (NMFS 2008b).

The 2008 FCRPS Biological Opinion RPA requires that the USACE install, and improve as needed, sea lion excluder gates at all main adult fish ladder entrances and must continue to support land and water based harassment efforts by NOAA Fisheries, ODFW, WDFW and the Tribes to keep sea lions away from the area immediately downstream of Bonneville Dam.

## 5.6 Predation, Competition and Disease

There has been an increase in abundance of predatory native and exotic fishes below Condit Dam within the reservoir created by Bonneville Dam. Primary predators of juvenile salmonids in the CR include northern pike minnow, smallmouth bass, channel catfish, walleye, terns, cormorants, and sea lions. Northern pike minnow are native cyprinids that are widely distributed throughout the CR Basin. Because these predators consume millions of salmonid smolts per year in the LCR, they are the subjects of an extensive predator control effort.

Hatchery steelhead juvenile releases into the White Salmon have probably led to competition with any natural-origin smolts produced below Condit Dam; these releases were discontinued in 2010. Hatchery adults that stray into the White Salmon River may compete for spawning and rearing habitat. Spawning of later returning URB fall Chinook salmon can reduce the productivity of naturally spawning tule fall Chinook salmon through redd superimposition.

Hatchery managers have reported Bacterial Kidney and Black Spot diseases throughout the White Salmon Basin (Allen et al. 2006a, 2006b). Now that PacifiCorp has breached Condit Dam, diseased fish moving into waters upstream of the former dam site may introduce other pathogens and/or diseases into the basin. The effects of disease on current or any potential future populations are unknown.

## 5.7 Ocean Conditions

The effects of ocean conditions on abundance of Pacific salmon and steelhead vary among species and populations within species. Migration patterns in the ocean may differ dramatically and expose different stocks to different conditions in different parts of the ocean. Some species have broad, offshore migration patterns that may extend as far as the Gulf of Alaska (steelhead, chum, and some Chinook salmon). Others have migration patterns along the Washington, British Columbia, Oregon, and California coasts (Chinook salmon, coho, and cutthroat salmon). Thus, ocean conditions do not have coincident effects on survival across species or populations.

Widespread changes in ocean conditions have dramatically affected ocean survival of steelhead. Cooper and Johnson (1992) showed that variation in steelhead run sizes and smolt-to-adult survival was highly correlated between runs up and down the West Coast. Smolt-to-adult survival rates generally varied 10-fold between good and bad years. Scientists know little about the early ocean life history of CR chum salmon.

## 5.8 Climate Change

Climate change represents a potentially significant threat to recovery of listed salmon and steelhead populations. The Independent Scientific Advisory Board (ISAB) for the NPCC, CR Basin Indian Tribes, and NMFS reviewed the potential effects of climate change on salmonids in the CR Basin (ISAB 2007). The ISAB report shows that changes in climate may adversely affect steelhead in freshwater habitats across the MCR DPS by exacerbating existing problems with water quantity (lower summer stream flows) and water quality (higher summer water temperatures). Impacts on snow pack, stream flow, and water quality in the Columbia Basin include the following (ISAB 2007):

- Warmer temperatures will result in more precipitation falling as rain rather than snow.
- Snow pack will diminish, and the timing of stream flow will be altered.
- Peak river flows will likely increase.
- Water temperatures will continue to rise.

These changes may affect steelhead more than other salmonids because of their long rearing period in freshwater.

Changing conditions could also affect salmonid health and survival in the ocean through a variety of mechanisms, including increased ocean temperatures, increased stratification of some waters, changes in the upwelling season, shifts in the distribution of salmonids, long-term variability in winds and ocean temperatures, increased acidity, and increased atmospheric and oceanic variability (NMFS 2007, 2008a; ISAB 2007).

All other threats and conditions remaining equal, future deterioration of water quality, water quantity, and/or physical habitat can be expected to cause a reduction in the number of naturally produced adult steelhead returning to these populations across the DPS. This possibility further reinforces the importance of achieving survival improvements throughout the entire steelhead life cycle. Recent research also indicates that neighboring populations with differences in habitat may show different responses to climate changes (Crozier and Zabel 2006; Crozier et al. 2008). This research reinforces the importance of maintaining habitat diversity.

## 5.9 Other Large-Scale Threats

Other large-scale threats that may affect salmon and steelhead populations in the White Salmon watershed in the future include the following:

- Human population growth. Pressures may increase for conversion of forestry and agricultural land uses to residential uses and residential water development, with potential impacts on habitat and water conditions.
- Increase in exotic invasive species that potentially compete with native flora and fauna. Such invasive species could provide food and/or cover to species that potentially compete with, prey on, or carry diseases that could affect native species.
- New diseases and/or pathogens. Migrating steelhead can introduce them through exposure to marine aquaculture operations or illegal stocking of out-of-watershed species, among other means.
- Natural catastrophic events.(e.g., earthquakes, volcanic eruptions, and large-scale forest fires).

Table 5-2 lists the primary factors limiting the production of fall Chinook salmon, the only extant population in the White Salmon River drainage. Table 5-3 lists the combined factors limiting the production of the extirpated or functionally extirpated spring Chinook salmon, coho, and chum salmon, and steelhead populations within the White Salmon watershed. Also listed are the potential impacts on population VSP parameters, sites where these impacts may be observed, the underlying anthropogenic threats, life stage affected, significance, and actions that would address the limiting factors.

**Table 5-2. Primary limiting factors for lower Columbia River fall Chinook salmon in the White Salmon River drainage**

| Limiting Factor | VSP Parameter Impacted | Sites Affected | Threats | Life Stages Affected | Significance (Scope/Severity) | Actions |
|---|---|---|---|---|---|---|
| Lack of spawning gravel and spawning area | Abundance, productivity | Lower 3.3 RM of mainstem White Salmon River | High fine sediment loads delivered from the former Northwestern Lake | Spawning and incubation | Fine sediments accumulated in the bottom of the former Northwestern Lake will be transported into the lower 3.3 miles of the river for potentially many years. These fine sediments will tend to settle out in lower gradient areas and will also tend to build up during lower flow periods. The net effect on habitat remains unknown. | Restoration of habitat in the reaches formerly occupied by Northwestern Lake and downstream of the former dam site. Natural processes will eventually come to an equilibrium. |
| Harvest | Abundance, productivity | All, but especially ocean and Columbia River fisheries | Commercial, recreational, and tribal fisheries | Upstream migration, ocean survival | Significant harvest of fall Chinook salmon is allowed annually. While the specified allowed harvest is expected to result in gradual population growth, the allowable rate of harvest may slow recovery | Modify fisheries |
| Genetic changes and/or competition with hatchery fish | Genetic diversity, abundance and productivity | All spawning areas | Strays from other areas | Spawning and rearing | Unknown | Monitor |

**Table 5-3. Additional factors potentially limiting anadromous fish (lower Columbia River spring Chinook salmon and coho salmon, Columbia River chum salmon, and middle Columbia River steelhead in the White Salmon River drainage). The primary limiting factors are highlighted in light yellow; factors that may become limiting in the future are highlighted in light gray.**

| Limiting Factor | VSP Impacted Parameter | Sites Affected | Threats | Life Stages Affected | Significance (Scope/Severity) | Actions |
|---|---|---|---|---|---|---|
| Lack of an extant viable population | Abundance and Productivity | All | Populations of steelhead, spring Chinook salmon, coho salmon, and chum salmon are considered extirpated or functionally extirpated | All stages | Re-colonization by the extirpated species will be limited to natural repopulation of the basin through straying | The preferred approach for reintroduction of species into the basin is to allow natural straying into the river. Hatchery alternatives may be implemented if population recovery is determined to be too slow. |
| Harvest | All | All | Now that the dam has been removed, an abundance of unoccupied habitat has become available. Harvest will directly affect the rate of species re-colonization and population growth. | All | Will delay the rate of recovery in direct proportion to the numbers of fish potentially spawning in the basin that are caught | Manage fisheries to increase the potential for escapement into the White Salmon River. |
| High sediment loads in the reaches formerly occupied by Northwestern Lake and the reaches downstream of the former lake and a lack of suitable spawning habitat downstream of Buck Creek | Abundance and Productivity, spatial structure and diversity | All | The high sediment loads mobilized out of the area of the former lake may eradicate suitable spawning habitat downstream of Buck Creek for many years. The absence of quality spawning habitat in the lower reaches may deter stray fish from moving into the upper basin where | All | May delay re-colonization of the basin | Implementation of PacifiCorp's Dam Decommissioning Plans. Additional analysis of both habitat and re-colonization rates will be required to determine if additional actions are needed. |

| Limiting Factor | VSP Impacted Parameter | Sites Affected | Threats | Life Stages Affected | Significance (Scope/Severity) | Actions |
|---|---|---|---|---|---|---|
| | | | good spawning habitat is available. | | | |
| **Factors that may become limiting as the populations grow** | | | | | | |
| Stream flow | Primarily abundance and productivity | Buck Creek | Water diversions. | Fry colonization, inactive age-0 and 1, juvenile rearing, migration | Diversion withdraws 70 percent of flow from Buck Cr., while unused portion returns to White Salmon via gully | Address Buck Creek water diversion |
| Large Woody Debris abundance | Primarily abundance and productivity | Mainstem White Salmon upstream of Buck Creek and lower White Salmon River mainstem. | Removal of wood for recreation; land use practices that reduce riparian forests | Fry colonization, juvenile rearing, overwintering, pre-spawners, spawners | Lack of LWD reduces pool habitat, sediment sorting and habitat complexity | Place LWD as appropriate and feasible. Address wood removal by boaters. Add structure to form pools |
| Stream temperatures | Abundance, productivity, spatial structure and diversity | Indian and Rattlesnake Creeks, lower Buck Creek, and possibly the reaches formerly occupied by Northwestern Lake | Land use practices that reduce riparian function; lack of riparian vegetation within the footprint of the former Northwestern Lake | Juvenile rearing, active age-0, spawning, migration | Currently the problem exists primarily in Rattlesnake and Indian Creeks, but may become a problem in the reaches previously occupied by the reservoir. | Increase shading along temperature limited reaches. |
| Harassment, predation and competition | Primarily abundance, productivity | Bonneville Pool | Inundation by Bonneville Pool | Adult migrants, pre-spawners, holding | Increase in exotic species and recreational activity in lower river | Improve programs that target exotic piscivorous fish in the mainstem Columbia |

# 6 Recovery Strategy and Actions

The preceding chapters summarize recovery goals, biological and threats criteria, current status assessment, and the major limiting factors and threats identified for the White Salmon River salmon populations. How will we reach recovery? The White Salmon recovery strategy contains two key parts: 1) a plan for reintroducing naturally produced salmon and steelhead into historical habitat after the removal of Condit Dam, 2) improving and increasing freshwater habitat for salmon and steelhead production in key reaches of the watershed. The Plan also recommends ensuring that harvest or hatchery actions do not impede efforts to improve salmon and steelhead viability.

Blocked passage at Condit Dam was the primary limiting factor for both salmon and steelhead until the dam was breached in October 2011, and completely removed in October 2012. The methods considered to reintroduce salmonids to their historical habitat, included natural re-colonization, artificial propagation, or some combination of the two. Section 6.1 and Appendix I describe reintroduction plans.

Sections 6.2 through 6.5 also propose additional actions regarding freshwater habitat, hatcheries, harvest, and hydrosystem operations.

## 6.1 Salmon and Steelhead Reintroduction Plans

The White Salmon Working Group, made up of Federal, state, and tribal fisheries managers, as well as representatives of PacifiCorp (Condit Dam operators), developed several options to consider for the reintroduction of salmon and steelhead into the White Salmon River. The group fleshed out each option with a description of the biological basis for the approach, operational and maintenance needs, and monitoring and evaluation needs. For more details about the options and considerations, see Appendix I.

Some members of the White Salmon Working Group proposed that after Condit Dam removal or passage restoration, the reintroduced/re-colonized populations in the White Salmon River be experimental populations pursuant to section 10(j) of the ESA. However, these fish would not meet the ESA's definition for an experimental population, which is defined, in part, as one that is "wholly separate geographically from non-experimental populations of the same species."

After the removal of Condit Dam, populations of Chinook salmon, coho salmon, and steelhead cannot remain "wholly separate geographically" from other populations within the listed ESU/DPS. Keeping the populations "wholly separate" from the other populations within the listed species is also not consistent with the recovery strategy where the goal is for listed species from neighboring populations to re-colonize the habitat above Condit Dam after its removal. Furthermore, as Sections 2.4.4 and 6.1.5 (MCR steelhead) describe, the steelhead population in the White Salmon River still evidence some of its ability for anadromy and is not wholly extirpated.

### 6.1.1 Fall Chinook salmon

The White Salmon Working Group agreed on a salvage plan for tule fall Chinook salmon to maintain natural production assuming Condit Dam removal. Beginning in 2008, biologists tested a salvage plan to see if technicians could capture enough adult tule fall Chinook salmon below Condit Dam and safely transport them to spawning habitat above the dam. Biologists monitored the transported tule fall Chinook salmon to determine post-release survival, movement, and spawning habitat preferences (Engle and Skalicky 2009). In 2009, technicians installed a weir at the White Salmon Ponds site and tested increasing adult salmon collection and estimating escapement above the White Salmon Ponds site (Engle et al. 2010).

The White Salmon Working Group evaluated the following options for tule fall Chinook salmon (see Appendix I for detailed descriptions).

1. Salvage adipose present CWT-negative tule fall Chinook salmon from the White Salmon River in the fall of 2010 to start tule fall Chinook salmon restoration.
2. Spring Creek NFH would spawn adults and rear eggs. The hatchery would acclimate and release the resulting juveniles at White Salmon Ponds.
3. Salvage adipose present CWT-negative tule fall Chinook salmon returning to Spring Creek NFH to start tule fall Chinook salmon restoration.
4. Outplant adults, adipose present, in 2011 above Condit Dam prior to removal.
5. No salvage effort in the White Salmon River or at Spring Creek NFH. Salvage adipose present CWT-negative tule fall Chinook salmon returning to the White Salmon River and outplant above Condit Dam prior to removal.

The White Salmon Working Group selected the outplant option (Option 4) for tule fall Chinook salmon because they believed that the habitat currently available above Condit Dam that can support natural spawning tule fall Chinook salmon and because this option would minimize the potential impacts of hatchery rearing. Biologists tested a number of collection alternatives 2008 to ensure that technicians could collect unmarked tule fall Chinook salmon in adequate numbers and safely transport them above Condit Dam (Engle and Skalicky 2009). In 2008, the goal was to transport up to 500 adults made up of marked hatchery fall Chinook salmon collected in the lower White Salmon River and fall Chinook salmon from Spring Creek NFH. Hatchery fall Chinook salmon were used for this test because Condit Dam did not have a system to safely pass juvenile salmon during their outmigration. In 2008, technicians collected 90 adults in the White Salmon River and transported 333 adults from Spring Creek NFH to habitat above Condit Dam (Engle and Skalicky 2009).

Monitoring of the transported adults determined the movement of adults after release, where spawning occurred, and determined that spawning was successful. The White Salmon Working Group is finalizing an operating plan for collection and transportation of adult tule fall Chinook salmon in 2010 (see Engle and Skalicky 2009). In 2009, technicians installed a weir and tested it adjacent to the White Salmon Ponds, using the historic weir location to collect more tule fall Chinook salmon adults (Engle et al. 2010). In 2011, prior to Condit Dam breaching, a total of 679 tule fall Chinook salmon were collected from the lower White

Salmon River and transported and released between Husum Falls and Northwestern Lake, of these 552 were determined to be natural-origin. Furthermore, spawning ground surveys determined that spawning was successful below Husum Falls (R. Engle, USFWS, November 2012, personal communication).

### 6.1.2 Spring Chinook salmon

The White Salmon Working Group reviewed the following options for reintroducing spring Chinook salmon into White Salmon River (see Appendix I for detailed descriptions).

1. Natural colonization, i.e., no active reintroduction efforts from outside sources.
2. Wild Klickitat spring Chinook salmon as brood source for juvenile release into the White Salmon River. Eggs collected and reared at Klickitat Hatchery, juveniles acclimated and released at White Salmon Ponds.
3. Klickitat Hatchery spring Chinook salmon as brood source for juvenile release into upper White Salmon River, starting in the spring of 2010 (from Klickitat Hatchery thinning release or other surplus juveniles).
4. Klickitat Hatchery integrated stock spring Chinook salmon as brood source for juvenile release into White Salmon River, in future years (broodstock source would be hatchery-reared offspring of wild fish).
5. Transport surplus Klickitat Hatchery adults to White Salmon starting in the fall of the year of removal.
6. Trap and transport Klickitat wild adults to White Salmon starting in the fall of the year of removal.
7. Monitor natural escapement and production for 4-5 years then evaluate need and suitability of Option 4.

The White Salmon Working Group decided on Option 7 for spring Chinook salmon. Under this option Working Group members propose to monitor escapement of spring Chinook salmon into the upper White Salmon River, including the proportion of Carson stock hatchery spring Chinook salmon on the spawning grounds. The Working Group also will monitor spring Chinook salmon smolt production in the upper White Salmon River. The 4-5 year monitoring period will determine if natural production is occurring and the source of that production. The monitoring period will also allow time for the development of the Klickitat Hatchery integrated spring Chinook salmon program and determine whether production capacity at this facility is available. The White Salmon Working Group considered the Klickitat Hatchery spring Chinook salmon program the best source of broodstock for reintroduction, even though it is not part of the LCR Chinook salmon ESU because it is within the transition zone between LCR and interior CR populations (Ford et al. 2011). The two nearest populations of spring Chinook salmon within the LCR ESU are in the Lewis River in Washington and the Sandy River in Oregon. Each of these basins have spring Chinook salmon hatchery programs but reintroduction efforts in the Lewis River Basin require current local production, while broodstock collection and funding shortfalls constrain production in the Sandy River. The result is the unavailability of a suitable source

of spring Chinook salmon stock to support the reintroduction efforts in the White Salmon River. NMFS is currently reviewing whether a population re-established in historic habitat using a non-ESU spring Chinook salmon stock can be part of the listed ESU for recovery and delisting purposes. The Hood River spring Chinook salmon recovery efforts are using a non-ESU spring Chinook salmon stock for reintroduction.

### 6.1.3 Coho salmon

The White Salmon Working Group reviewed the following options for reintroducing coho salmon into White Salmon River (see Appendix I for detailed descriptions).

1. Natural re-colonization, i.e., no reintroduction efforts from outside sources.
2. Juveniles from Washougal and/or Bonneville/Cascade hatcheries released into White Salmon River.
3. Collection of wild adult broodstock in Klickitat River with spawning and rearing at hatchery facility and juvenile release in White Salmon River.
4. Collection of wild adult broodstock in White Salmon River with spawning and rearing at hatchery facility and juvenile release in White Salmon River.
5. Monitor natural escapement and production for 4-5 years then evaluate need and suitability of Options 2, 3 or 4.

The White Salmon Working Group decided on Option 5 for coho salmon. As described for spring Chinook salmon, the Working Group members propose to monitor escapement, hatchery- and natural-origin coho salmon on the spawning grounds, and juvenile production in the White Salmon River Basin. Sources of stray hatchery coho salmon include releases from Bonneville Hatchery and releases into the Klickitat and Umatilla River basins. All of these releases derive from hatchery programs that are part of the LCR coho salmon ESU. A recovery team will use the results of the monitoring efforts to determine future reintroduction activities.

### 6.1.4 Chum salmon

The White Salmon Working Group reviewed the following options for reintroducing chum salmon into White Salmon River (see Appendix I for detailed descriptions).

1. Natural re-colonization, i.e., no reintroduction efforts from outside sources.
2. Active adult outplanting in years after Condit Dam removal.
3. Active stocking of juvenile chum salmon or outplanting of eggs in egg baskets and hatch boxes via WDFW's Washougal Hatchery or Willard NFH.
4. Initiate temporary hatchery program for chum salmon using existing USFWS hatcheries for subsequent outplanting of chum salmon captured at Bonneville Dam.

The White Salmon Working Group decided on Option 1 for chum salmon. The group chose this option because of the uncertainty regarding the status of chum salmon above Bonneville

Dam. This option calls for expanded spawning ground surveys in the Bonneville Pool using the mainstem chum salmon spawning habitat criteria developed for the population below Bonneville Dam. Those conducting surveys should focus in the lower reaches of suitable tributaries and include habitat suitability assessments for the reservoir and the tributaries.

### 6.1.5 Steelhead

The White Salmon Working Group reviewed the following options for reintroducing steelhead into White Salmon River (see Appendix I for detailed descriptions).

1. Natural re-colonization, i.e., no reintroduction efforts from outside sources.
2. Wild donor from local watershed as brood source for juvenile release into the White Salmon River. Eggs collected and reared at suitable hatchery and juveniles acclimated and released at White Salmon Ponds.
3. White Salmon resident *O. mykiss* as brood source, with locally suitable anadromous wild donor stock spawned for juvenile release into upper White Salmon River.
4. White Salmon steelhead captive brood program using captured outmigrating juveniles.
5. White Salmon steelhead kelt reconditioning. Recondition local spawners to enhance survival.

Based on the potential to re-establish natural production of steelhead in the basin, the White Salmon Working Group decided that Option 1, natural re-colonization, was the best approach. Indications that the (resident) population of *O. mykiss* in the White Salmon River above Condit Dam still produces smolts, even though the construction of Condit Dam and the end of passage in 1913 eliminated anadromy, was the basis of the group's decision. Recent monitoring in the White Salmon River above Condit Dam has identified *O. mykiss* juveniles displaying smolt behavior and morphology. Biologists detected juveniles PIT-tagged in Rattlesnake Creek passing Bonneville Dam, with one recovered at the tern colony on East Sand Island (B. Allen, personal communication, 2007). In addition, biologists detected a juvenile *O. mykiss* PIT-tagged above Condit Dam in September 2004 at 98 mm ascending Bonneville Dam in July 2006. Genetic analysis of juvenile *O. mykiss* collected in the upper watershed above Husum Falls found differences from hatchery trout released in the basin; additional samples are needed, however, to confirm this finding (Allen et al. 2006).

Additional research by Carmichael (Ruzycki 2003) in the Grande Ronde and by Thrower et al. (2004) in Alaska has identified a potential strategy for steelhead in the White Salmon. Research conducted by Thrower et al. (2004) indicated that:

> after 70 years of freshwater residency, a formerly anadromous, wild, freely breeding population of *O. mykiss* has retained large amounts of genetic variability associated with growth, precocious maturation and smolting despite complete selection against the phenotypic expression of at least one of the fitness related characters (smolting migration) critical for the re-establishment of an anadromous population…. Genetic potential for smolting can lie dormant or be maintained through a dynamic

> interaction between smolting and early maturation for decades despite complete selection against the phenotype. The results have significant implications for the preservation of threatened anadromous stocks in fresh water and the inclusion of resident fish of formerly anadromous populations, currently trapped behind longstanding barriers to migration, as one component of the same population.

This information supports the theory that even though the population is functionally extirpated, there is some the potential for re-establishing anadromous steelhead in the White Salmon River Basin. Using resident *O. mykiss* above Condit Dam will provide a genetic link to historical anadromous *O. mykiss*.

### 6.1.6 Monitoring and Evaluation

The key to the success of all of these options is to implement all of the proposed monitoring and evaluation activities, including development and implementation of an approach to monitor adult escapement, adult movement, presence/absence of stray hatchery-origin salmon and steelhead, and population productivity. In the future, if the need arises, and after careful evaluation and consensus among the co-managers, biologists could use a weir to exclude hatchery-origin adults, thus creating a refuge for naturally produced salmon and steelhead. Another reason that the White Salmon Working Group supported these options was that the removal of Condit Dam provides a rare opportunity to study the natural re-colonization of newly available habitat without using hatchery intervention. The proposed White Salmon Recovery Board and NMFS will evaluate the proposed options and make an assessment after 5 years to determine the next steps for reintroduction of salmon and steelhead in the White Salmon River.

Much remains unknown about the current status of the historical salmon and steelhead populations in the White Salmon and the capability of the habitat to support increased production. This Plan proposes the following actions to establish a baseline of current population status and habitat conditions and to help ensure that efforts to reintroduce salmon and steelhead in the White Salmon are efficient and successful. The YN, USGS, WDFW, USFWS, and UCD identified these actions. Chapter 8 offers further discussion of basin-wide monitoring and evaluation activities.

Biologists need to gather data and analyze information needs upstream and downstream of Condit Dam now that PacifiCorp has removed the dam. This information will inform project selection and implementation and improve the rate and success of reintroduction.

Below is a description of a multi-agency cooperative process for planning reintroduction. Table 6-1 summarizes the biological objectives, actions, and existing strategies for data gathering and analysis; it also outlines some needed habitat restoration. The YN, USGS, WDFW, USFWS, and UCD agreed to these general biological objectives and provided the detailed actions for which they would accept responsibility. In 2012, the White Salmon Working Group will work to refine the monitoring and evaluation plan to reflect the removal of Condit Dam in 2011.

Various management entities have implemented some of these monitoring and evaluation activities starting in 2006 and continued these activities through the removal of Condit Dam

(e.g., Allen et al. 2006; Smith et al. 2007). Recovery planners are seeking funding to continue the monitoring post-dam removal.

**Table 6-1. Biological objectives, management strategies, and actions to enhance/reintroduce anadromous salmonid populations and acquire baseline habitat information in the White Salmon River Basin**

| Biological Objective | Full Description | Actions and Existing Strategies |
|---|---|---|
| Implement reintroduction plan | Salmon and steelhead will be allowed to naturally re-colonize habitat above the former Condit Dam. Intensive monitoring activities will be implemented, including implementation of a program designed to monitor adult and juvenile abundance | Continue monitoring activities already occurring in the basin and expand to include population monitoring in the White Salmon River and Rattlesnake Creek |
| Complete gathering of information on existing salmonid stocks | Determine the status, life histories, and genetic composition of fish populations in the White Salmon River and its tributaries that are now accessible to anadromous salmonids. | Finalize adult and juvenile monitoring program for existing stocks in the White Salmon River. Assess interaction of bright and tule Chinook salmon populations and rainbow and steelhead |
| Hatchery status monitoring | Monitor the proportion and origin of hatchery salmon and steelhead on the spawning grounds | Continue to count adipose marked and unmarked carcasses and tagged adults |
| Maintain genetic diversity of listed salmonids | Continue to monitor current salmonid species composition and viability to determine effects of reintroduction actions | To maintain the genetic diversity of salmonid species in the White Salmon River complete analysis of information that describes the stocks and genetic diversity that currently exists |
| Population status monitoring | Monitor salmon and steelhead spawning escapement to estimate viable salmonid population parameters | Estimate population abundance using statistically robust methodologies |
| Assess effect of anadromous fish on resident fish | Assess the resident fish population prior to the reintroduction of anadromous salmonids | Assess resident trout contribution to smolts. Establish comprehensive monitoring program (of trout population). Assess change in resident population after steelhead re-colonization/reintroduction begins |

## 6.2 Freshwater Habitat Strategies and Actions

This plan proposes a number of freshwater habitat strategies and actions to rebuild the salmon and steelhead populations in the White Salmon River drainage to the desired levels of viability. The Plan recognizes that anadromous salmonids did not occupy the habitat upstream of the former Condit Dam; therefore habitat upstream of the dam was not limiting the population. However, now that the river upstream of the dam is becoming accessible, and anadromous salmonids are beginning to use this habitat, factors such as head cutting at the head of the old reservoir and the practice of removing large woody debris could limit the carrying capacity of the existing habitat. The factors limiting the populations during the process of rebuilding will be habitat affected by dam removal, or an out-of-basin factor such as harvest, predation, or ocean conditions which affects the rate of population growth.

Habitat downstream of the dam currently affects salmon production. With the removal of Condit Dam, the habitat downstream of the dam has changed dramatically and the habitat within the footprint of the existing reservoir may be of very low quality. Restoration of the habitat in those areas will be a priority.

Restoration of upstream habitats is also included in this Plan. Salmonids will eventually fully occupy the upstream habitats. Immediate initiation of restoration activities in the upstream habitats will ensure that quality habitat is available as the populations grow.

Maintenance and protection of existing high quality habitats to ensure no net loss in quantity or quality of existing available habitat can also be an important element in providing for the development of salmonid populations in the basin. Land use planning, implementation of BMPs, acquisitions, easements, cooperative agreements, protective land designations, and voluntary commitments are potential tools for protecting and maintaining high quality habitat.

The Plan defines four freshwater habitat strategies: 1) gain information needed to identify and prioritize habitat actions that will provide the greatest opportunity to contribute to recovery, 2) restore mainstem habitat downstream of Buck Creek, 3) protect and conserve existing natural ecological processes, 4) improve habitat in upriver reaches. The fourth strategy addresses habitat improvement in upriver reaches that anadromous populations have recently begun to occupy. Because the fourth strategy does not address a known limiting factor, it is therefore a broad-sense strategy. The White Salmon Working Group defined the strategies and actions through review and analysis of currently available information. Many reaches in the White Salmon watershed have quality habitat and functional ecological processes that are currently capable of supporting anadromous fish populations or have moderate habitat quality and quantity and the potential to become high quality habitat (White and Cochrane 2005; Morris 2003, 2004, 2005; Allen et al. 2006a, 2006b; White and Plumb 2004, 2005). The strategies and actions address risks that the TRT identified in viability assessments for the populations.

This Plan designed the strategies and actions together to protect and improve freshwater habitat in the drainage and, thus, improve the potential productivity of White Salmon salmonid populations. The Plan's actions to restore passage and habitat also expect to benefit other anadromous and resident species, including cutthroat trout and Pacific lamprey

(*Lampetra tridentata*), a candidate for ESA listing and an important food source for members of the YN. Table 6-2 summarizes the strategies and actions related to improvement of freshwater habitat. Table 6-3 summarizes proposed habitat related actions associated with the fourth strategy: improve habitat that anadromous populations may eventually occupy.

**Table 6-2. Primary biological objectives, management strategies, and actions to improve habitat in the White Salmon River watershed**

| Biological Objective | Species | Full Description | VSP Parameter Addressed | Actions and Existing Strategies |
|---|---|---|---|---|
| Gain information needed to identify and prioritize habitat actions that will provide the greatest opportunity to contribute to recovery | All species | Complete habitat surveys to help prioritize restoration needs and measure select habitat attributes above and below Condit Dam to document changes associated with removal of the dam as well as documenting time to recovery | All | An assessment of existing conditions is needed to prioritize recovery efforts |
| Restore mainstem habitat downstream of Buck Creek | All species | The effects of dam removal can only be estimated. With the dam removed, surveys will need to be conducted to a) document the habitat conditions immediately after removal, b) document changes in habitat over time, and c) identify and prioritize habitat restoration projects | All | Restore habitat through the implementation of PacifiCorp's Decommission Management Plans<br><br>Complete surveys following dam removal. Identify and implement priority actions for habitat restoration such as bank stabilization of restoration of native vegetation. |
| Protect and conserve existing natural ecological processes. | All species | Protection and conservation of existing habitat will ensure that quality habitat is available as populations grow and will help to avoid additional impacts to habitats currently in use | All | • Land use planning to minimize anthropogenic effects<br>• Land acquisition and conservation<br>• Adoption and management of conservation agreements<br>• Application of BM P BMPs<br>• Public outreach to educate river uses and others |

| Biological Objective | Species | Full Description | VSP Parameter Addressed | Actions and Existing Strategies |
|---|---|---|---|---|
| Restore riparian vegetation along stream sections that exceed state standards for temperature | All species | Some stream segments within the expected range of anadromous salmonid distribution are known to be excessively warm. Since it takes time to grow trees that will eventually provide shade, planting of trees and implementing other programs to restore and protect riparian conditions is desirable in the near term | All | • Identify stream segments that are excessively warm within the expected anadromous salmonid distribution<br>• Where riparian trees are sparse, implement programs to increase the density of the riparian vegetation<br>• Implement programs to protect existing riparian vegetation |

**Table 6-3. Biological objectives, management strategies, and actions to improve habitat in the upper White Salmon River watershed**

| Biological Objective | Species | Full Description | VSP Parameters Addressed | Actions and Strategies |
|---|---|---|---|---|
| **Additional Freshwater Habitat Strategies and Actions Addressing Likely Future Limiting Habitat Factors and Habitat Quality** | | | | |
| Improve habitat in upriver reaches | All populations | Protect and conserve natural ecological processes that support the viability of populations and their primary life history strategies throughout their life cycle<br><br>Priority locations: Rattlesnake Creek, Indian Creek, Buck Creek, White Salmon River (Buck Creek to Husum Falls), | All Parameters | • Protect highest quality habitats through acquisition and conservation<br>• Adopt and manage conservation agreements<br>• Consistently apply BMP BMPs and existing laws to protect and conserve natural ecological processes<br>• Provide public outreach to educate river uses and others |

| Biological Objective | Species | Full Description | VSP Parameters Addressed | Actions and Strategies |
|---|---|---|---|---|
| | | Spring Creek | | |
| | All populations | Gain information needed to identify and prioritize habitat actions that will provide the greatest opportunity to contribute to recovery<br><br>Priority locations: Watershed areas above Buck Creek, with emphasis on the mainstem | All | • Conduct habitat surveys to help prioritize restoration needs<br>• Implement projects to improve habitat |
| | All populations | Restore passage and connectivity to habitats blocked or impaired by artificial barriers<br><br>Priority locations: Buck Creek | Abundance<br><br>Productivity<br><br>Spatial Structure | • Remove or replace barriers blocking or impairing passage including dams, dikes, road culverts, and irrigation structures<br>• Provide screening at 100 percent of irrigation diversions<br>• Replace screens that do not meet criteria |
| | All populations | Reduce nutrient loads; Nutrient levels in the White Salmon Basin are high (White and Plumb 2005; White and Cochrane 2005). The nutrient enrichment may decrease juvenile or adult fish survival. A rehabilitation strategy is recommended. Monitoring will help determine if actions taken have improved the situation | Abundance<br><br>Productivity<br><br>Spatial Structure | • Reduce runoff from septic tanks<br>• Reduce nutrient runoff from dairies and agricultural lands |
| | All populations | Improve floodplain connectivity and function and channel migration processes | Abundance<br><br>Productivity | • Reconnect side channels and off-channel habitats to stream channels<br>• Restore wet meadows<br>• Reconnect floodplain to channel |

| Biological Objective | Species | Full Description | VSP Parameters Addressed | Actions and Strategies |
|---|---|---|---|---|
| | | Priority locations: Rattlesnake Creek, Indian Creek, Buck Creek, White Salmon River (Buck Creek to Husum Falls), Spring Creek | Spatial Structure | • Relocate or improve floodplain infrastructure and roads<br>• Conduct public awareness and education about restoration efforts |
| | All populations | Improve channel structure and complexity<br><br>Priority locations: Rattlesnake Creek, Indian Creek, Buck Creek, White Salmon River (Buck Creek to Husum Falls), Spring Creek | Abundance<br><br>Productivity | • Place stable wood and other large organic debris in streambeds<br>• Stabilize streambanks<br>• Restore natural channel form |
| | All populations | Improve riparian condition and LWD recruitment<br><br>Priority locations: Rattlesnake Creek, Indian Creek, Buck Creek, White Salmon River (Buck Creek to Husum Falls), Spring Creek | Abundance<br><br>Productivity | • Restore natural riparian vegetative communities<br>• Develop grazing strategies that promote riparian recovery<br>• Eradicate invasive plants species from riparian areas |
| | Steelhead<br><br>Spring Chinook salmon<br><br>Coho salmon | Reduce anthropogenic effects on hydrograph to provide appropriate flows during critical periods<br><br>Priority locations: Rattlesnake Creek, Indian Creek, Buck Creek | Abundance<br><br>Productivity | • Implement agricultural water conservation measures<br>• Improve irrigation conveyance and efficiency<br>• Restore natural functions and processes through actions identified in strategies above<br>• Employ BMPs to forest, agriculture, and grazing practices and to road management<br>• Protect and/or rehabilitate springs<br>• Increase pool habitat<br>• Restore wetlands and other water holding capacity on plateau |

| Biological Objective | Species | Full Description | VSP Parameters Addressed | Actions and Strategies |
|---|---|---|---|---|
| | All populations | Reduce summer water temperatures<br><br>Priority locations: Rattlesnake Creek, Indian Creek, Buck Creek | Abundance<br><br>Productivity | • Improve riparian vegetation<br>• Reduce sediment inputs to streams |

### 6.2.1 High Priority Reaches for Habitat Protection/Restoration and Proposed Actions

The White Salmon Subbasin Plan (NPCC 2004) identifies the following areas as high priority reaches for protection and restoration (based on anticipated potential distribution):

- Steelhead habitats are likely concentrated in the White Salmon River mainstem upstream to Husum Falls and in Rattlesnake Creek. The reach between Husum Falls and Big Brother Falls, RM 16.2, may also contain potential habitat. Rattlesnake Creek has an abundance of rainbow trout as well as numerous restoration opportunities.
- Spring Chinook salmon will likely concentrate in habitats in the mainstem reaches downstream of BZ Falls, RM 12.4. This habitat area would include the reaches downstream of the former Condit Dam, the footprint of the reservoir, and reaches between Buck Creek and BZ Falls. With the dam's removal, significant, high priority restoration opportunities exist.
- Coho salmon would likely utilize both the lower river and the upper river habitats, including the tributaries (Rattlesnake, Spring, and Buck creeks).
- Fall Chinook salmon are likely to concentrate in areas downstream of Condit Dam, and upstream as far as Husum Falls after passage resumes.
- Chum salmon are likely to concentrate near the mouth of the White Salmon River.

The following areas rank as the highest priorities for habitat restoration. Reasons for their ranking and actions proposed to address limiting factors and threats are summarized below based on information provided in White and Cochrane (2005), Morris (2003, 2004, 2005), Allen et al. (2006a, 2006b), White and Plumb (2004, 2005), EDT modeling results (Allen and Connolly 2005), the White Salmon Subbasin Plan (NPCC 2004), and Klickitat Lead Entity Region Salmon Recovery Strategy (Klickitat Lead Entity 2005).

***White Salmon River Mainstem - Site of Condit Dam, RM 3.3***

Achieving multiple DPS/ESU population recovery goals depends largely on the success of efforts to restore passage to upriver spawning and rearing habitats and improve flow and habitat conditions in the lower river.

Actions:

- The complete removal of Condit Dam to provide unimpeded upstream passage by adult and juvenile salmonids.
- Improve flow and habitat conditions in the lower White Salmon River.

***White Salmon River Mainstem - Mouth to Condit Dam***

After breaching, sediment loads below the dam site have increased, directly impacting fall Chinook salmon present in the reach at the time of dam removal. Sediment loads will impact potential spawning and rearing habitat for Chinook salmon, chum and coho salmon in the lower White Salmon River, and will impact the migration corridors for all anadromous species. An assessment of conditions after dam removal will determine the best approach to restoration.

Actions:

- Restore habitat through the implementation of PacifiCorp's Decommissioning Management Plan.
- Assess limiting habitat features due to dam removal and restore habitat as needed to provide for spawning, rearing, and adult holding and migration.
- Place LWD and gravel as appropriate.

***White Salmon River Mainstem - Condit Dam to Buck Creek***

This reach currently contains the section under the former Northwestern Reservoir. It should provide important habitat for salmon and steelhead spawning, rearing, migration, and adult holding after the effects of the Condit Dam removal are addressed. Large quantities of sediment have accumulated in the reservoir since the original owners built the dam in 1913. With the dam's removal, it may require years for the river to establish a stable channel. The banks of the river will tend to slough and erode until they reach a stable angle of repose and attain sufficient vegetation to reduce erosion and stabilize slopes. The time needed to re-establish a stable channel with clean gravels is unknown. Recovery planners and fish managers could take actions to hasten restoration. Biologists cannot identify the precise set of actions with any confidence until they evaluate the habitat conditions post-dam removal.

Actions:

- Restore habitat through the implementation of PacifiCorp's Decommissioning Management Plan.
    - Assess habitat-limiting features and identify restoration needs.
    - Implement projects to restore habitats, including planting of native vegetation.

***White Salmon River Mainstem - Buck Creek to Husum Falls***

This reach extends from the headwaters of the former Northwestern Lake to Husum Falls. The reach has high potential for salmon and steelhead spawning, rearing, and adult holding. USFWS also listed the mainstem White Salmon River up to Husum Falls as proposed critical habitat for bull trout; that same habitat is important for coastal cutthroat trout. Habitat in the reach generally remains in good condition. Therefore, recovery planners proposed no actions, though as use by anadromous fish increases, an assessment of the habitat in this section should be completed.

### *White Salmon River Husum to BZ Falls*

There is little data available regarding habitat conditions between Husum and BZ Falls. This reach would likely support coho salmon and steelhead and possible spring Chinook salmon. Biologists generally think the reach is in good condition, making restoration in this reach a lower priority. The primary action for this section would be to assess habitat features and restore habitat as needed to provide for spawning, rearing, and adult holding and migration.

### *Rattlesnake Creek*

Rattlesnake Creek and its tributaries provide significant spawning and rearing habitat for rainbow trout and likely highly productive habitat for coho salmon and steelhead once fish can pass to these upstream areas. The reach has low quality pools, excessive fine sediment in some spawning gravels, limited instream cover, and high summer stream temperatures in some areas (Morris 2003, 2004, 2005, White and Plumb; 2004, 2005, White and Cochrane 2005, Allen et al. 2006a, 2006b). Alders dominate riparian areas and limit long-term wood recruitment potential (Allen et al. 2006a; 2006b).

Actions:

- Protect functional riparian areas.
- Place LWD and other instream structure as appropriate to create pools, increase cover, and retain spawning gravels.
- Restore floodplain connectivity.
- Restore wetlands and other water holding capacity on the plateau through use of check dams and other methods.
- Establish conifers in riparian areas.
- Plant trees to reduce sediment input from banks.
- Implement measures to reduce cattle impacts to stream.

### *Buck Creek*

Buck Creek provides potential spawning and rearing habitat for coho salmon and steelhead. Biologists believe that habitat quality is currently limited because of insufficient pools and spawning gravels, low summer flows, and unscreened agricultural diversion. No data currently supports these suppositions, except for that relating to temperature. Available data indicate that temperatures in Buck Creek meet WA state standards (White and Plumb 2004; White and Cochrane 2005).

Actions:

- Conduct habitat studies to identify limiting factors within Buck Creek.
- Place LWD and other instream structure, as appropriate, to create pools and retain spawning gravels.

- Assess instream flows and initiate actions to improve base flow.
- Screen agricultural diversion and improve passage at irrigation diversion.

***Spring Creek***

Spring Creek may provide productive habitat for reintroduced anadromous coho salmon and steelhead runs. Production potential is currently limited because of decreased habitat diversity and increased sediment. Biologists have not evaluated the factors limiting habitat in Spring Creek.

Actions:

- Conduct assessments to identify factors
- Protect or improve instream wood and functional riparian areas as necessary.
- Place LWD as appropriate.

## 6.3 Hatcheries

Artificial production may play a role in the recovery of salmon and steelhead populations in the White Salmon. The White Salmon Working Group has proposed a strategy to allow for the natural re-colonization of the White Salmon River after Condit Dam removal. As described above in section 6.1, biologists will evaluate the natural re-colonization of the newly accessible habitat and, if escapement and productivity goals are not being achieved, then the White Salmon Working Group or a new recovery planning body will consider additional strategies using artificial propagation. Innovative programs, such as those employed by the Yakima/Klickitat Fisheries Project, as described in the Klickitat Anadromous Fisheries Master Plan (YN 2008), would be consulted and appropriate methodologies adopted (Table 6-4).

## 6.4 Harvest-Related Strategies and Actions

WDFW will continue to manage non-tribal fisheries for selective fisheries that target marked hatchery salmon and steelhead, requiring the release of unmarked (wild) fish. Overall impacts are very low for these tributary fisheries, with impacts generally less than 5 percent of the naturally produced fish (NPCC 2004).

In 2009, the recreational fishing regulations in the White Salmon River prohibited the retention of unmarked Chinook salmon from April 1 to June 30 and closed the river to retention of all Chinook salmon ½ mile above the Hwy 14 Bridge from October 1 to December 31. Fishing regulations prohibit retention of wild (unmarked) coho salmon and unmarked Chinook jack salmon (Chinook salmon less than 24 inches) in the White Salmon River annually from July 1 to March 31. Fishing regulations also prohibit retention of chum salmon in tributary recreational fisheries.

Mainstem harvest will continue to be managed through the *U.S. v. Oregon* process, and will be subject to consultation with NMFS. Co-managers will incorporate enhanced public education and non-tribal fisheries along with new selective fisheries regulations to ensure understanding and compliance.

Treaty Indian fishing rights in the Columbia basin are under the continuing jurisdiction of the U.S. District Court for the District of Oregon in the case of *U.S. v. Oregon*, No. 68-513 (filed in 1968). The parties to *U.S. v. Oregon* are the United States acting through the Department of Interior (USFWS) and BIA and Department of Commerce (NMFS), the Warm Springs, Umatilla, Nez Perce, Yakama, and Shoshone-Bannock Tribes, and the states of Oregon, Washington, and Idaho. In *U.S. v. Oregon*, the Court affirmed that the treaties reserved for the tribes 50 percent of the harvestable surplus of fish destined to pass through their usual and accustomed fishing areas.

A new *U.S. v. Oregon* Management Agreement has been completed, and NMFS has completed a section 7 Biological Opinion addressing the impacts of the fisheries management action and hatchery production in the new agreement (NMFS 2008c). The new management agreement will cover CR fisheries management and hatchery production actions from 2008 to 2017.

During the last 10-15 years, *U.S. v. Oregon*, the CR Fish Management Plan and successor agreements that contain restraints on the fisheries necessitated by ESA listings have managed harvest regulations. The agreements quantify and allocate between tribal and non-tribal fishing subject to ESA-imposed constraints for listed species (Table 6-4).

## 6.5 Hydro-Related Strategies and Actions

Actions to address out-of-watershed hydro-related limiting factors and threats are included in the recently released 2008 FCRPS Biological Opinion (NMFS 2008b). (Available at https://pcts.nmfs.noaa.gov/pls/pcts-pub/pcts_upload.summary_list_biop?p_id=27149) (accessed April 11, 2012).

Within the White Salmon River watershed, removal of Condit Dam will achieve the goals of restoring flows to the 1.1-mile bypass reach; recruiting gravel to the lower 3 miles of river; and, in the long-term, restoring MCR steelhead spawning habitat. Removal will also provide unimpeded movement of adult and juvenile lower Columbia salmonids (fall Chinook salmon, coho, and chum salmon) in the White Salmon River (Table 6-4).

**Table 6-4. Summary table addressing hatchery, harvest and hydrosystem-related recovery strategies and actions**

| Priority Strategies | Populations Affected and Addressed | Key Types of Actions | VSP Parameters Addressed | Potential Limiting Factors Addressed |
|---|---|---|---|---|
| **Hatchery** | | | | |
| Restore natural production into historically utilized habitats, including blocked areas above the former Condit Dam | All populations | • Monitor escapement and natural re-colonization of historical habitat<br>• Develop preferred option from reintroduction plan based on monitoring of natural re-colonization | All parameters | Lack of native stock |
| **Harvest** | | | | |
| Manage harvest for low impact fisheries and reduce harvest-related adverse effects in those fisheries that have significant impacts | All populations | • Manage harvest for low impact fisheries<br>• Adjust tributary harvest regulations in areas where harvest significantly impacts salmon and steelhead population growth | Abundance<br>Productivity | Commercial, recreational, and tribal fisheries in ocean, mainstem CR and tributaries |
| **Hydrosystem Issues and Mainstem Predation** | | | | |
| Maintain or improve hydropower operations and facilities at Bonneville Dam to enhance salmon and steelhead survival | All populations | • Maintain surface passage routes to improve juvenile passage at Bonneville Dam<br>• Decrease water travel time during smolt outmigration<br>• Improve operation of adult passage<br>• Maintain high standards for adult fish passage at Bonneville Dam | All parameters | Hydrosystem development and operations in mainstem CR alter steelhead migration conditions and delay passage. |
| Reduce predation on, and competition between, salmonids | All populations | • Reduce predation by pinnipeds<br>• Reduce predation by piscivores<br>• Reduce predation by cormorants<br>• Reduce predation by and relocate Caspian terns | Abundance<br>Productivity | Hydrosystem development and operations in mainstem CR increase predation on, and competition between, salmonids. |

# 7 Implementation and Cost Estimates

NMFS recognizes that there are significant uncertainties regarding expected future habitat conditions, that actions will need to restore habitat, and that actions require successful recolonization of salmonid populations in the White Salmon River watershed. NMFS is committed to an ongoing effort to address these uncertainties. This will require rigorous application of an adaptive management process that identifies key uncertainties, proposes competing hypotheses, and uses recovery actions and appropriate research and monitoring to test these hypotheses and adjust management accordingly.

Recovery is achievable only through the combined and coordinated actions of Federal and state agencies, tribes, and local governments, and with the participation of non-profit organizations, the business sector, and citizens. Collectively, NMFS refers to these parties as implementing partners. It will be essential that a collaborative implementation structure be set up to improve communication and work on a shared sense of priorities.

## 7.1 Implementation

The Washington Gorge Implementation Team (WAGIT) will coordinate implementation of the recovery plan for the White Salmon River watershed. The WAGIT is comprised of Klickitat County, the Yakama Nation, Washington Department of Ecology, Washington Department of Fish and Wildlife, the United States Geological Service, NMFS, the Central Klickitat and Underwood Conservation Districts, and various other stakeholders such as the Middle Columbia Regional Fisheries Enhancement Group. Representatives of the White Salmon Working Group are also participating on the WAGIT.

Implementation is being facilitated through the various existing programs in the area, including harvest management programs, the Yakama Nation Fisheries Program, Washington's Lead Entity Process, watershed planning and implementation processes initiated under state regulations and coordinated through the Klickitat County, various state and local habitat and watershed programs, and the various programs administered by the conservation districts. The WAGIT chose to draw upon and work within the many ongoing programs rather than developing a parallel, potentially duplicative process.

A balance between the biological benefit of a recovery action, its cost, and feasibility of implementation provides the basis for the WAGIT prioritization framework. Projects that address primary limiting factors, have high biological benefit to listed fish, are relatively inexpensive, and are feasible, receive highest funding priority. Projects with high cost, low biological benefit to listed fish species, and relatively low feasibility receive lowest funding priority.

Funding sources for salmon and steelhead recovery actions in the Columbia basin vary. They include:

- Pacific Coastal Salmon Recovery Fund (PCSRF) (states and tribes)
- Salmon Recovery Funding Board (SRFB) (a combination of PCSRF and Washington State funds)
- Columbia Basin Fish Accords
- Congressional appropriations (Federal agencies)

- State appropriations (state agencies)
- NPCC Fish and Wildlife program (states and tribes)
- Federal/state grants
- Non-profit organization programs and grants

## 7.2 Costs

NMFS, in coordination with the WAGIT and the White Salmon Working Group, provided cost estimates for implementing the White Salmon River Recovery Plan. The team developed cost estimates for a range of actions necessary to successfully reestablish anadromous fish populations in the White Salmon River watershed. There are numerous research, monitoring, and evaluation actions, specified in this Plan. Completed RM&E studies will help identify priority projects. In the absence of needed information, NMFS developed interim cost estimates for all potential recovery actions. NMFS and the area biologists estimated that RM&E actions will cost roughly $1,540,000 over a 5-year period. Chapter 8 provides further discussion of monitoring. Implementing PacifiCorp's decommissioning plans for Condit Dam is estimated at $0.9 to $1.1 million. Habitat actions related to the dam decommissioning could cost up to $15,100.000. The total cost over a 5-year period for restoring anadromous populations in the White Salmon River is estimated to be $16,781,000 (Table 7-1). More detailed information regarding these costs is provided in Appendix IV, White Salmon River Implementation Schedule: Summary of Actions and Potential Costs to Restore White Salmon River Anadromous Fish Populations and Their Habitat.

**Table 7-1. Summary of potential costs to restore the White Salmon River fish populations and their habitat**

| ACTION CATEGORY | COST |
|---|---|
| **Implementation of PacifiCorp's decommissioning plans** | **$900,000 to 1,100,000** |
| **RM&E** | **$1,540,000** |
| **Habitat Restoration and other actions** | **15,100,000** |
| **Hydrosystem and Mainstem Predation** | **Not Estimated** |
| **TOTAL** | **$16,781,000** |

The action categories listed in Appendix IV are derived from Chapter 6 Recovery Strategy and Actions. In many cases the specific actions provided in Appendix IV offer more detail than that described in Chapter 6. This is particularly true with regard to data collection and population monitoring. As discussed in Chapter 6, there is uncertainty regarding the primary factors that will limit the White Salmon populations in the long-term. Proposed data collection will fill those data gaps and provide direction for specific habitat restoration actions.

# 8 Monitoring, Research, and Evaluation for Adaptive Management

The various research and monitoring efforts proposed and underway in the White Salmon watershed regarding salmon and steelhead reintroduction, habitat restoration, and other activities require comprehensive empirical monitoring data on fish populations and habitat to identify appropriate project actions and strategies, select suitable sites and priority locations for actions, populate habitat/production capacity modeling efforts (such as EDT and All H's Analyzer [AHA]), and inform adaptive management for the salmonid recovery plan. Needed is additional information on fish distribution, abundance, productivity, habitat conditions, genetic diversity, pathogen levels, and other population parameters, as well as on population limiting factors. White Salmon recovery also requires a coordinated monitoring program to meet these various needs, as well as to help direct and evaluate the recovery effort.

## 8.1 Designing a Monitoring and Evaluation Program to Support Adaptive Management

Because of the length and complexity of the salmonid life cycle, there are many uncertainties involved in improving salmonid survival. To simply identify cause-and-effect relationships between any given management action and the characteristics of salmon populations can be a scientific challenge. It is essential to design a monitoring and evaluation program that will answer these basic questions: How will we know we are making progress? How will we get the information we need? How will we use the information in decision-making?

Designing an effective monitoring program for salmon recovery involves the following initial steps:

1. Clarify the questions regarding policy and management decision-making. Include the full ESU and the full salmonid life cycle.
2. Identify entity or entities responsible for coordinating development of this program.
3. Identify:
    - Which populations and associated limiting factors to monitor.
    - Metrics and indicators.
    - Frequency, distribution, and intensity of monitoring.
    - Tradeoffs and consequences of these choices.
4. Assess the degree to which existing monitoring programs are consistent with NMFS guidance.
5. Identify needed adjustments in existing programs, additional monitoring needs, and strategy for filling those needs.
6. Develop a data management plan (See Appendix B of *Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring*

*Guidance (May 1, 2007)* http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/upload/Adaptive_Mngmnt.pdf (accessed April 11, 2012).

7. Prioritize research needs for critical uncertainties, testing assumptions, etc.
8. Identify entities responsible for implementation.

## 8.2 Adaptive Management

Adaptive management means taking an experimental approach to a complex task, making one's assumptions clear, and continuously evaluating them in the light of new information. Adaptive management works best when the design of performance data collection and evaluation methods helps the information managers make sound decisions. As outlined in the NMFS *Adaptive Management* guidance document, several types of monitoring are needed: 1) implementation and compliance monitoring, which is used to evaluate whether the recovery plan is being implemented; 2) status and trend monitoring, which assesses changes in the status of an ESU (or a DPS) and its component populations, as well as changes in status or significance of the threats to the ESU (or the DPS); 3) effectiveness monitoring, which tests hypotheses and determines (via research) whether an action is effective and should be continued. In addition, it's important to build research to illuminate the many unknowns in salmon recovery - the "critical uncertainties" - that make management decisions all the more difficult.

NMFS' guidance document presents a decision framework (Figure 8-1) that can guide the design of a RM&E plan. The framework contains: 1) questions regarding ESU/DPS status (biological viability criteria); 2) questions regarding statutory listing factors and factors limiting recovery (limiting factor and threats criteria). Evaluating a species for potential delisting requires an explicit analysis of both types of criteria.

The guidance document contains a more detailed discussion of the framework and identifies the specific questions necessary to evaluate ESU/DPS status. These specific questions take the form of a series of decision-question sets that address the status and change in status of a salmonid DPS and the risks posed by threats to the DPS. NMFS designed the decision-question sets to elicit the information it needs to make delisting decisions. For recovery planners, the framework can guide future decisions about management strategies and actions aimed at achieving recovery goals.

The White Salmon monitoring and evaluation program will build on existing programs designed for monitoring tributary habitat in the White Salmon. The White Salmon monitoring and evaluation program will provide 1) a clear statement of the metrics and indicators by which progress toward achieving goals can be assessed; 2) a plan for tracking such metrics and indicators; 3) a decision framework through which new information from monitoring and evaluation can be used to adjust strategies or actions aimed at achieving the Plan's goals.

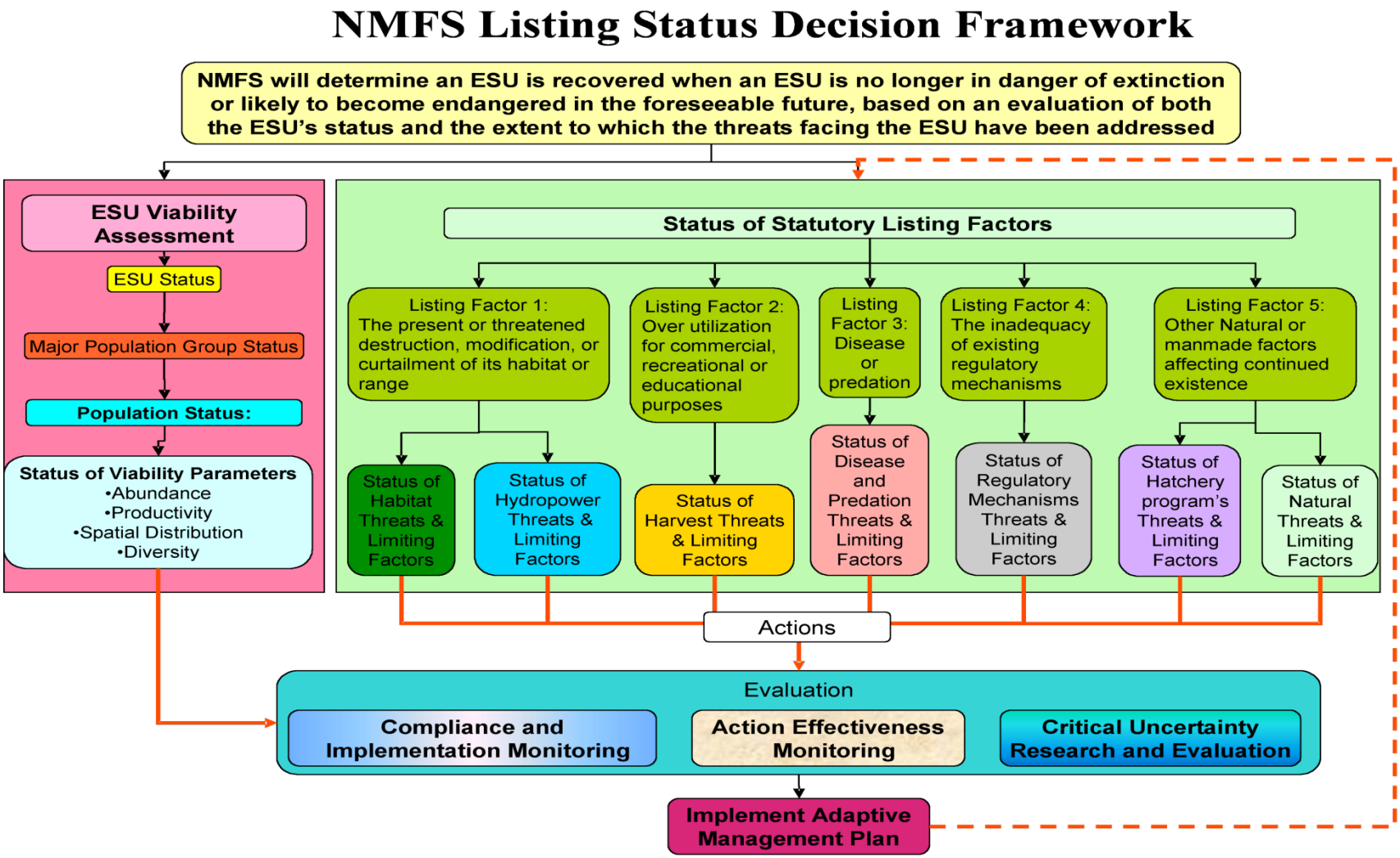


**Figure 8-1. NMFS Listing Status Decision Framework**

## 8.3 Critical Uncertainties

Data gaps important to recovery can be divided into two major categories: 1) those that deal with critical uncertainties; 2) gaps in knowledge about the linkages between specific actions and their effects on habitat factors and VSP parameters. Monitoring and evaluation will fill some of the data gaps; research will fill others.

Critical uncertainties, the unknown aspects of environmental conditions vital to salmonid survival, are a major focus of the RM&E program. To establish linkages between specific actions and resultant environmental effects will require monitoring. Those linkages are complex and often not well understood. Understanding them requires input from experts from various fields. It is important that the actions recommended in the Plan to benefit listed fish species in the White Salmon watershed be reviewed by fish ecologists, geologists, hydrologists, and other experts familiar with the recovery region.

The Plan expects that specific benchmark values for the VSP parameters will be refined during Plan implementation based on new information that addresses current uncertainties.

There are numerous out-of-basin uncertainties. The geographic areas that constitute the multiple ESU/DPSs encompass a large part of northern Oregon and a large part of southern Washington draining into the Columbia River. There are multiple populations across species. This context is significant in terms of uncertainties:

- Under the ESA, successful recovery of listed species as defined by NMFS requires achieving specific levels of productivity for populations within the entire ESU/DPS, not only acceptable productivity within any single basin that is a part of the ESU/DPS. Local communities in different watersheds/basins across local and state boundaries are dependent upon each other for successful delisting of these species.
- Of the seven necessary components of an ESA recovery plan, only three are the responsibility of in-basin parties - for which there is currently no collaborative governing board. The other components (e.g., hydropower operations, harvest, hatcheries, macro-economics, estuarine conditions), though significant to impacts on overall mortality, involve factors that are outside of the White Salmon watershed and actions taken within the watershed do not directly these factors. To measure the increases/decreases in productivity of the target populations before they migrate out of the watershed will require monitoring.

### 8.3.1 Research

As noted earlier, unknown aspects of environmental conditions vital to salmonid survival are termed “critical uncertainties.” Critical uncertainty research targets specific issues that constrain effective recovery plan implementation. This includes evaluations of cause-and-effect relationships between fish, limiting factors and actions that address specific threats related to limiting factors. Listed below are research actions to assess the effects of the uncertainties on recovery of listed fish species in the White Salmon watershed. Research actions address both in-basin and out-of-basin factors and are not all-inclusive. The

following lists in-watershed and out-of-watershed research needs. This list derives from a longer list identifying potential research needs for other basins within the ESUs and DPS.

### 8.3.2 In-Watershed Research Needs

- Determine fish abundance, origin, and production data after decommissioning of Condit Dam.
- Determine mainstem restoration needs after PacifiCorp's decommissioning plans have been implemented.
- Conduct habitat/population assessment work in Buck Creek.
- Track sediment downstream of Buck Creek through time.
- Monitor water quality after dam decommissioning.
- Assess impacts of dam removal on mainstem and tributary mouths above project area.
- Address potential issues at in-lieu fishing site after dam decommissioning.
- The White Salmon River is a thermal refuge. How important is this? What impact will this have on salmon and steelhead? Steelhead move into the White Salmon River to seek cold water refuge when mainstem Columbia River temperatures increase. What impact has dam-removal had on this condition?
- Increase understanding of linkages between physical and biological processes so that managers can predict changes in survival and productivity in response to selected recovery actions.
- Test assumptions and sensitivity of EDT and other model runs.
- Determine relative performance (survival and productivity) and reproductive success of naturally producing species.
- Assess population structure.
- Determine the effects of exotic species on recovery and the feasibility of actions to eradicate or control numbers of exotic species.
- Improve the understanding of the range of interactions between resident and anadromous forms of *O. mykiss*. The nature of the relationship is inherently complex and needs further evaluation, especially as recolonization begins to occur.
- Investigate instream flow needs for the mainstem White Salmon and tributaries that will support anadromous fish.

### 8.3.3 Out-of-Watershed Research Needs

- Monitor harvest levels.
- Develop better methods to estimate harvest of naturally produced salmon and steelhead and indirect harvest mortalities in freshwater and ocean fisheries.

- Assess the interactions between hatchery and naturally produced salmon and steelhead.
- Assess if hatchery programs increase the incidence of disease and predation on naturally produced fish.
- Evaluate increased predation risks from native and non-native fish, birds, and mammals.

These should be coordinated with NOAA's CR Estuary Recovery Plan Module (NMFS 2007) and the 2008 FCRPS Biological Opinion (NMFS 2008c).

## 8.4 Monitoring

The Plan includes direction for RM&E to: define unknown population characteristics, contribute to regional monitoring efforts, better direct efforts within the watershed, and assess the effectiveness of future actions.

Research and monitoring are designed to test implementation, validation, status/trend, and effectiveness. Implementation monitoring determines if the appropriate entities implemented the planned actions as intended and whether all implementation objectives are on schedule (section 8.1, Designing a Monitoring and Evaluation program to Support Adaptive Management). Status/trend monitoring determines the current conditions (status) of the populations and their habitats and their changes over time (section 8.2, Adaptive Management). Effectiveness monitoring focuses on whether the recovery actions changed the environment and/or the VSP parameters (section 8.3, Critical Uncertainties). Validation monitoring determines whether the fundamental ecological assumptions underlying the recovery plans are true. Prominent among these assumptions are the effects of specific environmental conditions on survival and abundance of listed fish species embodied in the EDT model. Researchers will determine which assumptions need testing once recovery planners fill the critical data gaps (section 8.3, Critical Uncertainties).

Conditions outside the watershed will affect and inform actions, research, and monitoring within the watershed. Out-of-basin conditions do and will have a significant effect on the success of recovery of species within the watershed. These factors include commercial harvest, sport and tribal harvest, conditions in the mainstem CR (including hydroelectric operations), and conditions in the estuary and ocean including short and longer term cycles in ocean conditions. The regional RM&E program developed under the FCRPS Biological Opinion will measure status, trends, and effectiveness of actions in this area.

A recently formed multi-agency Condit Technical Working Group (now White Salmon Working Group) met in early 2007 to discuss RM&E issues (and actions to resolve them) in light of the proposed removal of Condit Dam. The section "In-Watershed Research Needs" (below) the RM&E questions drafted during this meeting are detailed further.

*Key Question #1: What is the source of colonizing salmon and steelhead?*

Collect genetic samples after dam decommissioning and compare with samples collected prior to dam removal using genetic analysis.

*Key Question #2: Has the abundance and origin of salmon, steelhead, and bull trout spawners changed between pre- and post- dam removal?*

Compare pre-removal abundance of spring Chinook salmon, fall Chinook salmon, steelhead, and coho salmon with abundance post dam removal.

*Key Question #3: Has smolt production increased after dam removal?*

Compare smolt estimates pre-dam removal for Chinook salmon fry, and coho, Chinook salmon, and steelhead smolts (USGS) with smolt population estimates after dam removal.

*Key Question #4: Has the habitat changed after dam removal?*

Compare bathymetric surveys below Condit in the early 1990s with post-removal surveys. Conduct cross-sectional profiles just above reservoir and near mouth to document down-cutting and sediment transport.

Described below is a general framework for monitoring within the White Salmon watershed.

### 8.4.1 Implementation Monitoring

Effective RM&E requires implementation and compliance monitoring checks to determine whether action entities carried out the activities as planned and whether action entities met specified criteria as a direct result of an implemented action. Scientists will monitor recovery actions within the White Salmon watershed to assess whether action entities implemented the actions as planned. This monitoring will consist of an administrative review and will not require environmental or biological measurements.

Implementation monitoring will address the types, numbers, and locations of actions implemented and how much area or stream length each action affected. Indicators for implementation monitoring will include visual inspections, photographs, and field notes on numbers, location, quality, and area affected by an action. For example, if fencing is planned for 20 miles of stream corridor to keep livestock off the stream banks so that riparian vegetation will rebound, implementation monitoring would verify the presence of the fence. Compliance monitoring would take note of the presence or absence of livestock in the fenced-off area.

Comparing field notes with the specifications in the plans or proposals (detailed descriptions of engineering and design criteria) will determine success. Thus, design plans and/or proposals will serve as the benchmark for implementation monitoring. Evaluations will describe in detail any deviations from specified engineering and design criteria.

### 8.4.2 Status/Trend Monitoring

Status and trend monitoring is a compilation of data based descriptions of existing conditions. To be useful in decision-making, a scientist reduces the raw data, or metrics, to a more directly applicable form or indicator. For example, if the question is "What is the annual spawning population-size of steelhead in the White Salmon River?" The indicator would be total spawning numbers of steelhead over one season for the entire river basin. The metric, or directly measured thing, however, would be something quite different, perhaps

steelhead redds sighted on weekly passes over known spawning grounds. Thus, a scientist would process the metric to translate it from the metric data type (e.g., redds) into the indicator data type (e.g., spawners) and then summarize to generate the indicator required (e.g., from a list of weekly counts on spawning grounds to an annual total for the watershed).

A future collaborative board directing implementation will develop a program to monitor the status and trend of salmon and steelhead and their habitats throughout the White Salmon watershed. The program will utilize guidelines developed in the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) and the Collaborative System-wide Monitoring and Evaluation Project (CSMEP).

### 8.4.3 Effectiveness Monitoring

Effectiveness monitoring specifically addresses cause-and-effect questions. Demonstrating the direct and indirect impact of management actions requires supporting all steps in a logical chain that connects the action to its expected impact. This chain is rarely short and usually contains several hypotheses. For this reason, it's better to build the effectiveness monitoring into the recovery action strategies with, for example, pilot-scale tests or other methods carefully thought out beforehand.

Not all recovery actions the Plan recommends need monitoring to determine effectiveness. However, it is important that scientists assess a sufficient number of replicates of each "type" of action to assess effectiveness. To the extent possible, monitoring for recovery action effectiveness will use the Before-After-Control-Impact design with stratified random sampling, as described in the Comprehensive Statewide Monitoring Strategy (Monitoring Oversight Committee 2002). This strategy describes in detail the approach, indicators, and protocols needed to assess effectiveness of habitat restoration classes. It is critically important to coordinate the effectiveness monitoring programs with status/trend monitoring and effectiveness monitoring within the hydro sector.

Monitoring and evaluation will only provide the answers to the questions the RM&E designs intended to address. They do not provide the framework for revising questions that are ill posed. Evaluating the assumptions upon which the recovery planners built their strategy or incorporated learning into future action and strategy decisions is the role of adaptive management.

## 8.5 Consistency with Other Monitoring Programs

This recovery plan will utilize existing monitoring programs to evaluate the status/trend and effectiveness of recovery actions within the White Salmon watershed. Specifically, this approach will incorporate strategies, indicators, and protocols described in the Yakima/Klickitat Fisheries Project, the upper Columbia Monitoring Strategy, the Comprehensive Statewide Monitoring Strategy, and CSMEP. The development of other regional monitoring programs may result in modifications to the monitoring programs used in the White Salmon watershed. These other programs, in various states of development, include such approaches as PNAMP. As these programs develop more fully, they will provide guidance on valid sampling and statistical designs, measuring protocols, and data management. Scientists may use this information to refine and improve the existing

monitoring and evaluation programs in the White Salmon watershed. The intent is to make monitoring and evaluation programs in the White Salmon watershed consistent with programs throughout the Columbia basin as well as the ESUs and DPS.

## 8.6 Coordination

Many entities have been or will be implementing recovery actions within and downstream of the White Salmon watershed. Monitoring programs to coordinate with include:

- Yakima/Klickitat Fisheries project
- YN Monitoring
- NOAA Fisheries RM&E program
- Washington SRFB program
- PACFISH/INFISH Monitoring program
- Pacific Northwest Interagency Regional Monitoring program
- USFWS, USGS, and Bureau of Reclamation (BOR), monitoring programs
- WDFW and Washington Department of Ecology monitoring programs
- Washington Department of Ecology Watershed Assessment and Management Process (Revised Code of Washington (RCW) 90.82)
- Local UCD monitoring

It is critical that recovery planners consult with these programs to emphasize utility, reduce redundancy, increase efficiency, and minimize costs.

## 8.7 Evaluation Schedule

While the White Salmon watershed currently has no collaborative regional board guiding work, a regional board for the Washington Gorge Management Unit could develop as a follow-up to recovery planning. An appropriate first check-in for the watershed is 3 years from the adoption of the Plan. At this time, the board or co-managers should review efforts within the watershed - whether or not they have obtained funding and initiated actions. At years 5, 8, and 12 further evaluations should occur in order to coordinate with other watersheds in the ESUs and the middle Columbia Steelhead DPS. Reviews at this time should start with funding and implementation effectiveness. If funding and implementation have taken place previously, the RM&E program should review their effectiveness and measure progress toward the overall implementation of projects within White Salmon. The evaluation should place progress, or the lack thereof, within context of all the ESUs and the DPS.

The first major step in the adaptive management program is to obtain 5-year implementation schedules from each of the partners that describe the tasks, schedules, priorities, and estimated cost to implement the recovery actions. The RM&E program will request that each of the Federal and state agencies, tribal and local governments, and non-governmental

partners prepare an implementation schedule for their recovery actions. A regional implementation schedule covering the entire White Salmon Management Unit will combine these individual schedules. The recovery partners will complete their initial schedules in the summer of 2010; they will prepare new schedules annually incorporating changes or modifications based on implementation and effectiveness evaluations. NOAA Fisheries 5-year ESA status reviews should coordinated with additional evaluations of the status of viability attributes limiting factors and new information critical uncertainties. The White Salmon Recovery Plan should incorporate the results of these programs into adaptive management and coordinate with other middle Columbia steelhead recovery plans, the recovery plan estuary, and harvest modules for the CR, as well as the 2008 FCRPS Biological Opinion.

## 8.8 Monitoring and Evaluation Plan

The information in this chapter provides a framework for the development of a salmonid RM&E and adaptive management plan for the White Salmon Basin. When NMFS finalizes the recovery plan's goals and objectives, a process will begin to fully develop a RM&E plan with the White Salmon Working Group and append it to the recovery plan when the recovery plan is completed. A multi-agency salmonid reintroduction plan for the White Salmon River will rely heavily on results of research guided by ongoing monitoring and evaluation.

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# Appendix I. Options for Salmon and Steelhead Reintroduction

The following are reintroduction plans for salmon and steelhead in the White Salmon River that were developed by the White Salmon Working Group, made up of Federal, state, and tribal fisheries managers, as well as representatives of the PacifiCorp (Condit Dam operators). The White Salmon Working Group developed a number of options for the reintroduction of salmon and steelhead into the White Salmon River in anticipation of the removal of Condit Dam in the fall of 2009. Each option developed for the various salmon and steelhead populations includes a description of the biological basis for the approach, operational and maintenance needs, and the monitoring and evaluation needs to support the approach. Each of the Plans and assorted options that were developed are listed below, with the preferred option highlighted in gray.

**Tule Fall Chinook salmon**

Salvage Effort Options within the White Salmon River in Preparation of Removal of Condit Dam.

1. Salvage adipose present CWT-negative tule fall Chinook salmon from White Salmon River in fall 2010 to start tule fall Chinook salmon restoration. Eggs collected and reared at Spring Creek NFH, juveniles acclimated and released at White Salmon Ponds.

a. Biological Basis

   i. Would emphasize collection of adult returns that presumably are natural progeny from previous spawning populations in the White Salmon.

   ii. The mass marking protocol used at Spring Creek NFH would allow for identification of "wild" fish on the spawning grounds.

      1. Hatchery fish would be either adipose-fin clipped or have a CWT present.

      2. Wild fish would have adipose-fins present and no CWT.

b. O&M (Operation and Maintenance ) Needs

   i. Temporary weir construction at White Salmon Ponds.

      1. A salvage effort with fish wheel or active adult seining in Lower River to capture adipose present tule fall Chinook salmon could also be used in lieu of or in addition to weir.

         (a) Several options should be discussed for what efforts might be fiscally and logistically possible.

      2. New screens would be needed at the intake structure to comply with NOAA Fisheries or a waiver would be required to operate the ponds and weir during adult collections.

3. Potential need to coordinate with Condit Dam operations should flow manipulation need to occur for selected capture method.

ii. Eggs reared at Spring Creek NFH and transferred for acclimation at White Salmon Ponds for release in April or May per rotary trap timing of tule fall Chinook salmon.

1. Ponds need to be watered up and ready by spring following dam removal to be used for acclimation.

2. Potential upriver or alternative acclimation strategies could be used if White Salmon Ponds are not a viable option.

iii. Program Size

1. 1996 Columbia Basin Fish and Wildlife Authority (CBFWA) Document states 32,000 0+ juveniles for production and release. This translates into about 58 adults that will return based on SCNFH escapement estimates.

2. NMFS Draft White Salmon Recovery Plan states abundance recovery goal of 900 adults (TRT recommendations, pg 105).

3. White Salmon Subbasin Plan (using EDT analysis) estimates 792-995 for abundance estimation from historical through removal with PFC.

4. Based on adult escapement estimates for White Salmon, 500 to 600 adults might "fill out" escapement. The production goals would correlate to annual releases of 275,000 to 330,000.

5. Capacity at White Salmon ponds would be 300,000 for release.

iv. Need to revise HGMP from Spring Creek NFH

1. Would encompass tules and other stocks that may be acclimated at ponds (pending workgroup decisions).

c. RM&E Needs

i. Specific juvenile tagging of these fish is also needed to determine survival rates and evaluate the salvage action.

ii. Genetic analysis of adults collected for salvage effort in 2010.

1. Needed to properly assess success of salvage effort and also act as a baseline for monitoring hatchery/wild fish interactions on the spawning grounds for future years.

iii. Continuation of rotary trapping and genetic analysis to determine production of juveniles.

iv. Expansion of WDFW carcass surveys into areas above Condit dam in 2010 and beyond.

v. Some decision process to end production based on rotary trapping results of successful spawning abundance or on wild adult escapement estimates (might be easier to estimate).

2. Salvage adipose present tule fall Chinook salmon returning to Spring Creek NFH in fall 2009 to start restoration. Eggs collected and reared at Spring Creek NFH, with juveniles acclimated and released at White Salmon Ponds.

   a. Biological Basis

      i. Would emphasize collection of adult returns that presumably are natural progeny from previous spawning populations in the White Salmon.

      ii. Annual returns to Spring Creek NFH have some components that are presumed to be naturally produced fish.

         1. Fish that have their adipose fin and do not have a CWT.

         2. This would need to be verified by analysis of CWT return data in combination with scale analysis between CWT/adipose fin clipped fish and "wild" interceptions at the hatchery.

   b. O&M Needs

      i. Eggs reared at SCNFH and transferred for acclimation at White Salmon Ponds for release in April or May per rotary trap timing of tule fall Chinook salmon

         1. Ponds need to be watered up and ready by spring 2011, this should be 2010 if we are collecting in 2009, if going to be used for acclimation.

         2. Would need to modify screens or get a waiver from NOAA Fisheries.

         3. Potential upriver or alternative acclimation strategies could be used if White Salmon Ponds are not a viable option.

      ii. Program Size

         1. 1996 CBFWA Document states 32,000 0 + juveniles for production and release. This translates into about 58 adults that will return based on SCNFH escapement estimates.

         2. NMFS Draft White Salmon Recovery Plan states abundance recovery goal of 900 adults (TRT recommendations, pg 105).

         3. White Salmon Subbasin Plan (using EDT analysis) estimates 792-995 for abundance estimation from historical through removal with properly functioning conditions.

         4. Based on adult escapement estimates for White Salmon, 500 to 600 adults might "fill out" escapement. The production goals would correlate to annual releases of 275,000 to 330,000.

5. Capacity at White Salmon ponds would be 300,000 for release.

iii. Need to revise HGMP from Spring Creek NFH.

1. Would encompass tules and other stocks that may be acclimated at ponds (pending workgroup decisions).

c. RM&E Needs

i. Specific juvenile tagging of these fish is also needed to determine survival rates and evaluate the salvage action.

ii. Genetic analysis of adults collected for salvage effort in 2009.

1. Needed to properly assess success of salvage effort and also act as a baseline for monitoring hatchery/wild fish interactions on the spawning grounds for future years.

iii. Expansion of WDFW carcass surveys into areas above Condit dam in 2010 and beyond.

iv. Continuation of rotary trapping and genetic analysis to determine natural production of juveniles.

v. Some decision process to end production based on rotary trapping results of successful spawning abundance or on wild adult escapement estimates (might be easier to estimate).

3. No salvage effort in the White Salmon or at SCNFH

a. Biological Basis

i. Assumes natural colonization in the future.

ii. Would assume that sediment movement after dam removal would be large and allow for successful natural colonization immediately.

b. O&M Needs

i. None at SCNFH

c. RM&E Needs

i. Continuation of rotary trapping and genetic analysis to determine natural production of juveniles.

ii. Expansion of WDFW carcass surveys into areas above Condit dam in 2010 and beyond.

4. Outplant adults, adipose present, in 2010 above Condit Dam prior to removal.

a. Biological Basis

i. Assumes natural colonization and allows some spawning to occur above Condit Dam prior to removal.

ii. Would assume that sediment movement after dam removal would be large and allow for successful natural colonization in later years.

iii. Could be done in conjunction with any of the previous actions or for a number of years to allow for natural colonization.

b. O&M Needs

i. Radio-tagging and Peterson disc tagging of adults to determine movement to White Salmon.

c. RM&E Needs

i. Continuation of rotary trapping and genetic analysis to determine production of juveniles.

ii. Expansion of existing carcass surveys conducted by WDFW to monitor spawning above Condit Dam during 2009 and in 2010.

**Spring Chinook salmon**

1. Natural re-colonization - no active reintroduction efforts from outside sources.

a. Biological Basis

i. Probably very small number of returning native adults - may not be sufficient number to restart population.

ii. Concerns about Carson fish on spawning grounds?

b. O&M Needs - little to none

c. RM&E Needs

i. Monitor any natural spawner escapement.

ii. Monitor Carson fish on spawning grounds.

iii. Monitor smolt production.

2. Wild Klickitat spring Chinook salmon as brood source for juvenile release into the White Salmon River. Eggs collected and reared at Klickitat Hatchery, juveniles acclimated and released at White Salmon Ponds.

a. Biological Basis

i. Would emphasize collection of wild Chinook salmon from locally adjacent watershed, with similar geomorphologic characteristics and flow regime.

ii. No mass marking to minimize harvest to return as many spawners to White Salmon River as possible.

1. Hatchery fish would have unique CWT if determined that carcasses survey would be productive. More important to CWT after natural production is established.
2. Use PIT-tagging. Limited Wild fish would have adipose fins present and no CWT.

b. O&M Needs

i. New improved broodstock collection facility at Lyle Falls Fishway (~3 years out).

ii. Isolated spawning and rearing at Klickitat Hatchery - several options should be discussed for what efforts might be fiscally and logistically possible.

iii. White Salmon Pond rehabilitation and O&M.

iv. Juvenile transport at fry or smolt stage.

c. RM&E Needs

i. Monitor natural and hatchery escapement to spawning grounds.

ii. Monitoring natural escapement in Klickitat River (relatively low in recent years) and any impacts to natural population from broodstock collection.

3. Klickitat Hatchery spring Chinook salmon as brood source for juvenile release into upper White Salmon River, starting in spring 2010 (from Klickitat Hatchery thinning release or other surplus juveniles).

a. Biological Basis

i. Would emphasize use of hatchery Chinook salmon from locally adjacent watershed.

ii. Possible concerns about genetic mixing in Klickitat Hatchery stock of stream- and ocean-type Chinook salmon (see c.ii. below).

b. O&M Needs

i. Isolated spawning and rearing at Klickitat Hatchery - several options should be discussed for what efforts might be fiscally and logistically possible.

ii. Upper White Salmon release site identified/developed and O&M.

iii. Direct stream release locations identified/developed.

c. RM&E Needs

i. Fish Health monitoring (BKD concerns).

ii. Assessment of possible effects of use of genetically mixed Klickitat Hatchery stock (evidence of possible broodstock mixing of stream-type [spring-run] and ocean-type [summer-run] in Klickitat Hatchery stock).

4. Klickitat Hatchery integrated stock spring Chinook salmon as brood source for juvenile release into White Salmon River, in future years (broodstock source would be hatchery-reared offspring of wild fish).
    a. Biological Basis
        i. Would emphasize use of integrated stock Chinook salmon from locally adjacent watershed.
        ii. May alleviate concerns of broodstock mining effects on Klickitat wild population (pending success of program at Klickitat Hatchery).
        iii. Would likely alleviate concerns regarding use of current Klickitat Hatchery stock due to possible mixing of stream- and ocean-type Chinook salmon (see 3.c.ii above).
    b. O&M Needs - similar to Option 3 above.
    c. RM&E Needs - similar to Option 3 above (except for 3.c.ii).
5. Transport surplus Klickitat Hatchery adults to White Salmon starting in fall 2010.
    a. Biological Basis
        i. May be precluded by disease concerns resulting from out-of-basin transfer of adult fish.
        ii. Possible concerns about genetic mixing in Klickitat Hatchery stock of stream- and ocean-type Chinook salmon (see 3.c.ii. above).
    b. O&M Needs
        i. Trucking O&M.
        ii. Racking in of transported broodstock.
    c. RM&E Needs
        i. Radio-telemetry study.
        ii. Assessment of possible genetic effects (see 3.c.ii. above).
6. Trap and transport Klickitat wild adults to White Salmon.
    a. Biological Basis
        i. May be precluded by disease concerns resulting from out-of-basin transfer of adult fish.
    b. O&M Needs
        i. Trucking O&M.
        ii. Racking in of transported broodstock.

c. RM&E Needs

i. Monitor any natural re-colonization in interim (concerns about Carson fish?)

ii. Radio-telemetry study.

iii. Monitoring natural escapement in Klickitat River (relatively low in recent years) and any impacts to natural population from adult trap and transport.

7. Monitor natural escapement and production for 4-5 years then evaluate need and suitability of Option 4.

a. Biological Basis

i. Would determine if sufficient number of returning adults to restart population.

ii. Concerns about Carson fish on spawning grounds?

b. O&M Needs - little to none (unless Option 4 initiated).

c. RM&E Needs

i. Monitor any natural spawner escapement.

ii. Monitor Carson fish on spawning grounds.

iii. Monitor smolt production.

**Coho salmon**

1. Natural re-colonization - no reintroduction efforts from outside sources.

a. Biological Basis

i. Sufficient number of returning adults to restart population?

ii. Identification of coho benefits from EDT modeling efforts.

b. O&M Needs - little to none

c. RM&E Needs

i. Monitor natural spawner escapement.

ii. Monitor smolt production.

2. Juveniles from Washougal and/or Bonneville/Cascade hatcheries released into White Salmon River.

a. Biological Basis

i. Would use LCR coho stock for brood source (Washougal Hatchery, Lewis River, Type N, and/or Tanner Creek).

b. O&M Needs

i. Existing facilities at Washougal, Bonneville and Cascade hatcheries.

ii. For possible acclimation - White Salmon Pond rehabilitation and O&M.

iii. Juvenile transport at fry or smolt stage.

c. RM&E Needs

i. Monitor natural and hatchery escapement to spawning grounds.

ii. Monitor natural production.

iii. Fish health monitoring.

3. Collection of wild adult broodstock in Klickitat River with spawning and rearing at hatchery facility and juvenile release in White Salmon River.

a. Biological Basis

i. Would use nearby wild broodstock source.

b. O&M Needs

i. Identify suitable hatchery facilities for spawning and rearing.

ii. Adult capture facility at Lyle Falls Fishway on Klickitat River.

iii. For possible acclimation - White Salmon Pond rehabilitation and O&M.

iv. Juvenile transport at fry or smolt stage.

c. RM&E Needs

i. Monitor natural and hatchery escapement to spawning grounds.

ii. Monitor natural production.

iii. Fish health monitoring.

4. Collection of wild adult broodstock in White Salmon River with spawning and rearing at hatchery facility and juvenile release in White Salmon River.

a. Biological Basis

i. Would use local wild broodstock source.

b. O&M Needs

i. Identify suitable hatchery facilities for spawning and rearing.

ii. Adult capture facility - Weir or White Salmon Ponds rehabilitation.

iii. For possible acclimation - White Salmon Pond rehabilitation and O&M.

iv. Juvenile transport at fry or smolt stage.

c. RM&E Needs

i. Monitor natural and hatchery escapement to spawning grounds.

ii. Monitor natural production.

iii. Fish health monitoring.

5. Monitor natural escapement and production for 4-5 years then evaluate need and suitability of Options 2, 3 or 4.

a. Biological Basis

i. Would determine if sufficient number of returning adults to restart population.

ii. Identification of coho benefits from EDT modeling efforts.

b. O&M Needs - little to none (unless Options 2, 3, or 4 initiated).

c. RM&E Needs

i. Monitor natural spawner escapement.

ii. Monitor smolt production.

**Chum salmon**

1. Natural re-colonization - no reintroduction efforts from outside sources.

a. Biological Basis

i. Allows for natural colonization from populations within or below Bonneville pool.

b. O&M Needs

c. RM&E Needs

i. Continuation of either annual or every nth year chum surveys using revised chum specific "Patch" analysis or remote sensing techniques to monitor re-colonization efforts.

2. Active adult outplanting in years after Condit Dam Removal.

a. Biological Basis

i. Decreases timeframe of re-colonization and potentially provides better opportunity for multiple pairs of chum salmon to spawn in White Salmon.

ii. Most likely chum salmon are extirpated from White Salmon and chances for spawning to be occurring presently seem very unlikely.

iii. Accelerates building of chum population in White Salmon.

b. O&M Needs

i. Adults would have to be trapped in Bonneville Dam fishways or below Bonneville Dam (Ives Island, Duncan, Hardy and/or Multnomah Creek deltas) and trucked to release point in White Salmon River.

ii. Appropriate chum spawning channels could be constructed in suitable habitat within lower White Salmon River and adults transported into these channels.

c. RM&E Needs

i. Begin annual or every nth year surveys using chum specific "Patch analysis to monitor population dynamics.

ii. Identification of donor populations and determine both genetic and population fitness of these populations. (Below Bonneville stocks appear to be genetically best suited, and most easily obtained.)

iii. Identification of suitable spawning/outplanting locations and juvenile rearing habitat within White Salmon and lower tributaries.

iv. Potential PIT-tagging or Radio-tracking to determine spawning ground distribution and success or utilize remote sensing techniques.

3. Active stocking of juvenile chum salmon or outplanting of eggs in egg baskets and hatch boxes via WDFW's Washougal Hatchery or Willard NFH.

a. Biological Basis

i. Decreases timeframe of re-colonization and potentially provides better opportunity than natural re-colonization.

ii. O&M needs - yet to be determined but could involve infrastructure needs to Willard or Washougal hatcheries in addition to fish culture needs.

b. RM&E Needs

i. Continuation of either annual or every nth year surveys using chum specific "Patch analysis to monitor population dynamics.

ii. Identification of donor populations and determine both genetic and population fitness of these populations. (Bonneville fishway and or below Bonneville stocks appear most suitable and most easily obtained).

iii. Identification of suitable stocking locations and juvenile rearing habitat within the White Salmon River and lower tributaries.

iv. Potential PIT-tagging or Radio-tracking to determine distribution, timing and movement of chum salmon juveniles.

4. Initiate temporary hatchery program for chum salmon using existing USFWS hatcheries for subsequent outplanting using only chum captured at Bonneville Dam.

a. Biological Basis

i. Decrease risk to downstream donor stocks whose numbers are annually declining.

ii. Uses parent stock of chum salmon with fidelity to the Bonneville Reservoir and possible the White Salmon River.

iii. Decreases timeframe of re-colonization.

b. O&M Needs

i. Adults would have to be trapped in Bonneville Dam fishways.

ii. Adults would be held and spawned in Service Hatcheries.

iii. Eggs or juveniles would be outplanted in suitable habitat.

c. RM&E Needs

i. Survey and identify suitable habitats prior to outplanting.

ii. Evaluate success of any outplanted eggs.

iii. Continuation of either annual or every nth year surveys using chum specific "Patch analysis to monitor population dynamics.

iv. Potential PIT-tagging or Radio-tracking to determine distribution, timing and movement of returning adult chum salmon passing Bonneville Dam.

**Steelhead**

There are indications that the population of *O. mykiss* in the White Salmon River above Condit Dam is still producing smolts even though anadromy has been eliminated since the construction of Condit Dam and the end of passage in 1913. Pre-removal monitoring in the White Salmon River above Condit Dam has identified *O. mykiss* juveniles displaying smolt behavior and morphology, and PIT-tagged juveniles have been detected passing Bonneville Dam with one being recovered at the tern colony on East Sand Island (B. Allen, personal communication, 2007). In addition, a juvenile *O. mykiss* PIT-tagged above Condit Dam September of 2004 at 98 mm was detected ascending Bonneville Dam in July of 2006. Genetic analysis of juvenile *O. mykiss* collected in the upper watershed above Husum Falls are different from hatchery trout released in the basin, however additional samples are needed to confirm this finding (Allen et al. 2006). This information supports the theory that even though the population is functionally extirpated there is still the potential for re-establishing anadromous steelhead in the White Salmon River Basin.

Based on the potential to re-establish natural production of steelhead in the basin, the White Salmon Working Group decided that Option 1, the natural re-colonization approach, was the best suited for the status of *O. mykiss* in the basin. The key to the success of this option is to implement all of the proposed monitoring and evaluation activities, including screw trap operations and the installation of a weir on Rattlesnake Creek to monitor adult escapement, adult movement, and presence/absence of stray hatchery-origin steelhead. In the future, if the need arises, the weir could be used to exclude hatchery-origin adults creating a refuge for naturally produced steelhead. Another reason that the White Salmon Working Group

supported Option 1 was that the removal of Condit Dam provides a rare opportunity to study the natural re-colonization of newly available habitat without using hatchery intervention. Option 1 will be evaluated and an assessment made after 5 years to determine if the approach should continue or if the other proposed options should be considered.

1. Natural re-colonization - no reintroduction efforts from outside sources
    a. Biological Basis.
        i. Potentially a small number of returning native adults but may not be sufficient number to restart population.
        ii. Recent USGS studies identify PIT-tagged resident *O. mykiss* migrating from the White Salmon above Condit Dam. One PIT-tag collected at East Sand Island, and one detected passing back upriver through the Bonneville Dam fishway (steelhead life history may still be present in upper watershed).
    b. O&M Needs
        i. Maintenance of weir(s) in tributary stream(s).
    c. RM&E Needs
        i. Monitor all natural spawner escapements.
        ii. Monitor hatchery stray steelhead on the spawning grounds.
        iii. Juvenile fish surveys for abundance and growth (via PIT-tagging).
        iv. Rotary Screw Trap (both in lower river and above current reservoir site) to collect out migrants for DNA (deoxyribonucleic acid) analysis, and juvenile production.
        v. Adult and juvenile weir trap and/or instream PIT-tag detector for monitoring in Rattlesnake Creek.
        vi. Redd capping to conduct DNA analysis.
2. Wild donor from local watershed as brood source for juvenile release into the White Salmon River. Eggs collected and reared at suitable hatchery, juveniles acclimated and released at White Salmon Ponds.
    a. Biological Basis
        i. Would emphasize collection of wild steelhead from locally adjacent watershed, with similar geomorphologic characteristics and flow regime.
        ii. Marking to minimize harvest and still provide monitoring information on returning adults.
    b. O&M Needs
        i. White Salmon Pond rehabilitation and O&M.
        ii. Juvenile transport at fry or smolt stage.

iii. Possible identification and development of upriver acclimation site.

c. RM&E Needs

i. Monitor natural and hatchery escapement to spawning grounds.

ii. Monitoring natural escapement in brood source river and any impacts to natural population from broodstock collection.

3. White Salmon resident *O. mykiss* as brood source with locally suitable anadromous wild donor stock spawned for juvenile release into upper White Salmon River.

a. Biological Basis

i. Would emphasize both local (resident) and from locally adjacent watershed.

ii. Possible concerns of ESA status of new population.

b. O&M Needs

i. Upper White Salmon release site identified/developed and O&M.

ii. Possible identification and development of upriver acclimation site.

c. RM&E Needs

i. Fish Health monitoring (BKD/IHN concerns).

ii. Assessment of possible effects of use of genetically mixed local donor stock.

4. Develop White Salmon captive brood program using captured outmigrating juveniles.

a. Biological Basis

i. Capture genetically unique White Salmon steelhead for captive brood program development.

b. O&M Needs

i. Transport equipment.

ii. Spawning, incubation, rearing and adult holding facilities.

iii. Possible identification and development of upriver acclimation site.

c. RM&E Needs

i. DNA analysis to ensure White Salmon population.

5. White Salmon Steelhead Kelt Reconditioning. Recondition local spawners to enhance survival to repeat spawning stage.

a. Biological Basis

i. Maximize survival of White Salmon steelhead to bolster early stages of White Salmon re-colonization effort.

b. O&M Needs

i. Adult downstream weir trap to collect females.

ii. Holding area and feed.

iii. Direct stream release locations identified/developed (for release of reconditioned adults).

c. RM&E Needs

i. Monitoring holding/release methods (i.e. release below Bonneville, or release into White Salmon, hold and release into White Salmon just prior to spawning).

ii. PIT-tag adults for Bonneville Dam detection.

iii. Rotary Screw Trap (both in lower river and above current reservoir site) to collect out migrants for DNA analysis.

iv. Acoustic tag monitoring in White Salmon and Columbia plume to track kelt movement.

# Appendix II. Current Efforts and Regulations Addressing and Protecting Population Productivity in the White Salmon Watershed

## Population Enhancement and Habitat Restoration Actions

Positive change is underway to address limiting factors and threats to improve steelhead habitat conditions. A number of actions are proposed, being planned, or are already being implemented in the watershed to address these conditions and the affected populations.

Recent actions include:

- Planning for population introduction/reintroduction upstream of the former Condit Dam
- Plantings of trees in riparian zones to provide for future shade and LWD recruitment
- Assessment of habitat condition in Rattlesnake Creek to identify opportunities for future restoration actions
- Klickitat County expects to initiate the development of a White Salmon Watershed (WRIA 29b) Management Plan in the near future, pending the availability of funding

## Regulatory Protection

Federal, state, county, and tribal regulatory mechanisms are in place to protect habitat from current and future threats posed to listed species through habitat loss and degradation caused by human land uses and development. Numerous voluntary programs are also available to address habitat conservation. In addition, some areas receive special protection through designation, such as Wild and Scenic River reaches, primitive areas, and wildlife refuges.

### *NOAA Fisheries and/or U.S. Fish and Wildlife Section 7 Consultations*

Section 7 of the ESA directs all Federal action agencies to consult with NOAA's NMFS and the USFWS to ensure that all Federal actions/projects will not jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat. Actions include not only direct Federal actions, but also actions funded with Federal dollars. A Biological Assessment or Biological Evaluation is usually developed and submitted to NMFS for review prior to implementation of any project. The reader can find additional information regarding the consultation process at: http://www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/Hatcheries/Sec-7-USFWS-Columbia.cfm (accessed April 19, 2012).

### *Clean Water Act*

The Federal Clean Water Act addresses the development and implementation of water quality standards, the development of Total Maximum Daily Loads (TMDL), filling of wetlands, point source permitting, the regulation of stormwater, and other provisions related to protection of U.S. waters. The Clean Water Act is administered in the State of Washington by the WDOE with oversight by the EPA. State water quality standards are set to protect beneficial uses, which include several categories of salmonid use. Ecology has a

water quality certification program under which it reviews projects that will discharge dredged or fill materials into waters of the U.S. and issues certifications that the proposed action meets State water quality standards and other aquatic protection regulations, if appropriate. Ecology also issues National Pollution Discharge Elimination System (NPDES) permits, and develops water quality cleanup plans TMDL to address water quality limited streams.

### *National Environmental Policy Act (NEPA) Review*

NEPA requires Federal agencies to consider the probable impacts of their proposed activities, programs, and projects (including funding of state, local, and private actions) on the quality of the human environment. NEPA reviews help agencies decide whether to undertake a proposed action. In most cases, the NEPA review requires the development of an Environmental Assessment or Environmental Impact Statement (EIS) that addresses the probable effects of a project and its alternatives on various elements of the environment, including soils, geology, landscapes, atmospheric conditions, vegetation, fish and wildlife, and cultural resources. Many Federal funding programs are covered under a general NEPA review completed when the funding program was developed.

### *Watershed Planning Act*

In 1998 chapter 90.82 Revised Code of Washington (RCW) was amended with the passage of Engrossed Substitute House Bill (ESHB) 2514. This law is also known as the Watershed Planning Act. The Watershed Planning Act was established to address the diminishing water availability and quality, and the loss of habitat for fish in the State of Washington. The Watershed Planning Act provides a framework for local citizens, tribes, and state and local agencies to work together to develop and implement Watershed Management Plans for entire watersheds.

As part of the planning process, a watershed assessment is completed for each Water Resource Inventory Area (WRIA) to evaluate water supply and use. Once the watershed assessment is complete, a management plan, followed by a detailed implementation plan, is developed to address water quantity, water quality, and fish habitat issues identified in the assessment. The White Salmon River lies within WRIA 29b. Watershed planning activities are currently on hold due to the state's current budget shortfall.

### *State Environmental Policy Act (SEPA)*

SEPA regulations require an environmental review of actions taken by the state and local agencies, including funding and permitting. Some actions, such as the construction of single-family dwellings, minor road repair, and issuance of business licenses, are exempt. A SEPA review evaluates the probable environmental effects of a proposed project. This information is used to determine if the action should be taken as proposed, if mitigation is necessary, or if the proposal should be rejected.

### *Forest & Fish Regulations (Washington State)*

The Washington Forests & Fish Law, ESHB 2091, was signed into law in 1999 as part of The Washington State Forest Practices Act (Title 76.09 RCW), passed in 1974. The Forests

& Fish Law, based on the Forests & Fish Report, resulted in changes to forest practices rules to protect riparian and aquatic resources on more than eight million acres of private forestland. It is intended to meet the provisions of the Federal Clean Water Act concerning non-point source silvicultural practices. Changes to the law included:

- Updates of the stream typing system in the state to improve mapping of fish-bearing waters
- Increases in buffer widths along fish bearing and non-fish bearing streams,
- Changes in forest practices to protect against landslides
- Mandatory requirements to update the forest road system to hydrologically disconnect roads from streams and minimize sediment delivered to streams
- New regulations on pesticide applications to prevent or avoid drift of chemicals into streams
- Increased protection of wetlands
- Changes in enforcement
- Establishment of a scientifically based adaptive management and monitoring process for evaluating the impact of forest practices on aquatic resources
- Establishment of a process for amending the forest practices rules to incorporate new information as it becomes available
- Establishment of a small landowner office to assist non-industrial landowners

Additional information regarding the Forest Practices rules can be found at: http://www.dnr.wa.gov/BusinessPermits/ForestPractices/Pages/Home.aspx (accessed April 19, 2012).

The Washington Department of Natural Resources, on behalf of the State of Washington, submitted applications to NMFS and the USFWS for incidental take permits under section 10 of the ESA. Issuance of these permits would provide assurances that all forest practices activities in compliance with the state forest practices rules and administrative program will satisfy ESA requirements for aquatic species. The two services released the final HCP (habitat conservation plan), the final EIS, and implementing agreement in a ***Federal Register Notice*** on Jan. 27, 2006. This notice provides an opportunity for the public to review the final documents and the responses to public comments on the draft documents.

***Klickitat County Shorelines Master Plan***

In 1971 the Washington State Legislature passed the Washington Shoreline Management Act, adopted by public referendum in 1972. The purpose of the Act is "to prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines" by requiring every county and many cities to develop a Shoreline Master Plan to govern development in shoreline area http://www.ecy.wa.gov/programs/sea/sma/st_guide/intro.html (accessed April 19, 2012). Klickitat County's Shorelines Master Plan (SMP) was first adopted in 1975 and has been updated periodically since then. The SMP and brochure on the shorelines permit program can be accessed from the Klickitat County Planning Department's website: http://klickitatcounty.org/Planning/default.asp?fCategoryIDSelected=301427788 (accessed April 19, 2012).

The Klickitat County's SMP regulates "development" within the "shorelines" of the White Salmon River and other water bodies in Klickitat County's jurisdiction. "Development" is broadly defined as: construction or exterior alteration of existing structures; dredging; drilling; dumping; filling; removal of any sand, gravel or minerals; bulkheading; driving of piling; placing of obstructions; or any project of a permanent or temporary nature which interferes with the normal public use of the surface of the waters overlying lands subject to the SMP regulations at any state of water level. "Shorelines" are those lands extending landward for 200 feet in all directions as measured from the ordinary high water mark, floodways and contiguous floodplain areas landward 200 feet from such floodways; all wetlands and river deltas associated with the streams and lakes. The SMP applies to the shorelines of the mainstem of the White Salmon River as well as the shorelines of all tributaries with a mean annual flow of 20 cfs or more.

The SMP designates various shorelines of the White Salmon River and its tributaries as "environments", which determine the level of protection that is warranted. Much of the White Salmon River is designated either "Natural Environment" which prohibits most development within its shorelines or "Conservancy Environment", which allows a limited scope of development, subject to conditions (i.e., shoreline conditional use permit). Each development proposal is subject to review pursuant to the shoreline environment within which it is to be located. One or more shoreline permits must be secured prior to implementation: Substantial Development Permits are required for any development for which the total cost or fair market value exceeds $5,000, or any development which materially interferes with the normal public use of the water or shorelines; Shoreline Conditional Use Permits (CUP) are required for development types that warrant conditions to ensure consistency with the SMP; and Variances are issued to grant relief from specific bulk, dimensional, or performance standards of the SMP in order to avoid unnecessary hardship, provided that extraordinary circumstances are shown to exist and the public interest shall suffer no substantial detrimental effect. Some types of development, such as a single-family residence, normal maintenance and repair, or construction of a normal protective bulkhead for a single family residence, are exempt from the requirement of a substantial development permit, but are still subject to all other provisions of the SMP.

Existing structures and developments that were established prior to adoption of the SMP are considered legally established "non-conforming" uses. Since adoption of the SMP, the County and WDOE have reviewed all developments within shorelines, including modifications to non-conforming uses, to ensure compliance with the goals and requirements of the SMP.

The WDOE reviews the County's permit decisions and has final authority to approve or deny CUPs and Variances. Persons may appeal the final decision to the Shorelines Hearings Board.

### *Klickitat County Critical Areas Ordinance*

Klickitat County adopted a Critical Areas Ordinance (CAO) in 2001 and, with the concurrence of WDFW, Community Trade and Economic Development, and Ecology, amended it in 2004. The CAO extends beyond the geographical scope of the County's SMP

to protect wetlands, critical fish/wildlife habitat, geologically hazardous areas, aquifer recharge areas, and frequently flooded areas. The CAO is, in effect, an overlay on existing land use regulations. The CAO provides for standard setbacks of 300' from Category I wetlands, 200' from Category II, and 75' from Category III and IV. The CAO provides for standard buffers of 200' from Type 1 & 2 waters; 150' from Type 3 waters; 50' from Type 4 waters; and 25' from Type 5 waters. A wildlife habitat management plan is required for new development that will likely impair salmonid habitat functions and values. As with the SMP, developments and uses that existed prior to the adoption of the CAO are considered legally established "non-conforming" uses. The CAO and brochures land use permit programs can be accessed from the Klickitat County Planning Department's website: http://klickitatcounty.org/Planning/default.asp?fCategoryIDSelected=301427788 (accessed April 19, 2012)

***Klickitat County Floodplain Management Ordinance***

The Klickitat County Floodplain Management Ordinance (FPO) regulates all development and activities that may increase flood hazards. A permit is required for development within areas of special flood hazard (with at least one percent chance of flooding). The applicant for a non-residential structure must include a certification and flood analysis conducted by a professional engineer. In general, development that does not meet the specific criteria in the ordinance for development in these areas, to protect public health and safety, will be denied. The FPO and brochures land use permit programs can be accessed from the Klickitat County Planning Department's website: http://klickitatcounty.org/Planning/default.asp?fCategoryIDSelected=301427788 (accessed April 19, 2012).

***Klickitat County Zoning Ordinance***

The Klickitat County Zoning Ordinance (CZO) was adopted in 1979 and has been amended over time. Much of the White Salmon River watershed is zoned by the CZO as "extensive agriculture" which requires a 20-acre minimum lot size for the purpose of dividing properties, and new development/uses are restricted to resource management uses/activities and other compatible uses. One permanent residential dwelling is allowed per lot. Some areas of the watershed are zoned for residential development. The allowable minimum lot size for new lots is either 1 or 2 acres; and one residential dwelling is allowed per lot. Other than residential development, most new development/uses in these zones is either prohibited or allowed per a zoning conditional use permit. The CZO and brochures land use permit programs can be accessed from the Klickitat County Planning Department's website: http://klickitatcounty.org/Planning/default.asp?fCategoryIDSelected=301427788 (accessed April 19, 2012).

***Klickitat County Environmental Ordinance (CEO)***

The Klickitat County Environmental Ordinance (CEO) was adopted pursuant to the SEPA. The CEO and SEPA require an analysis of probable significant adverse environmental impacts that may result from a proposed development. The CEO and SEPA require a threshold determination for each proposed development that is not exempt. The threshold determination is a determination that a project will or will not have probable significant

adverse environmental impacts. If a project has probable significant adverse impacts, and an EIS is prepared, any proposed development/use that is not specifically exempt in SEPA, chapter 43.21C RCW, or the SEPA rules adopted by the Department of Ecology, Chapter 197-11 Washington Administrative Code, is required to comply with SEPA. Klickitat County provides applicable state agencies and tribes, as well as the public, the opportunity to review threshold determinations and EISs.

***Washington State Water Pollution Control Act (Chapter 90.48 RCW)***

This act gives Ecology the authority to protect water quality in the state and to promulgate regulations as needed to achieve this goal. The Act makes discharges of pollutants into waters of the state unlawful and has provisions for enforcement of violations, including the authority and process for issuing compliance orders and civil penalties, and for seeking criminal penalties. The Act also provides for permitting processes, cooperation with other entities, water quality monitoring, grants, and numerous other subjects regarding management of water quality issues in the state.

***Washington's Statewide Monitoring Program***

In 2001, Substitute Senate Bill (SSB) 5637 was signed into law. This act related to monitoring of watershed health and salmon recovery. The Monitoring Oversight Committee developed a comprehensive statewide strategy that addresses the actions identified in SSB 5637. Among other things, the Plan is intended to provide information regarding trends in fish, water, and habitat conditions and assess effectiveness of actions taken to improve watershed health and provide for salmon recovery. The strategy includes documentation of fish population trends in some areas of the state; however, the White Salmon River watershed is not one of the areas included to date in that monitoring effort. The strategy is also monitoring the effectiveness of habitat restoration efforts funded by the state. The monitoring of project effectiveness follows the Monitoring and Evaluation Strategy (Washington SRFB 2003) that was developed in support of the Comprehensive Statewide Strategy. The Monitoring and Evaluation Strategy specified methods to assess a wide range of restoration and protection projects.

***On-Site Sewage Systems***

Chapter 246-272 of the Washington Administrative Code regulates the onsite disposal of sewage in the state. The law is applicable to septic systems as well as larger on-site systems. The rule addresses location of systems, site evaluations, design, installation, inspection, operation and maintenance, repair, abandonment, and other areas of concern. The rule helps to prevent the discharge of sewage into fish-bearing streams.

***Hydraulic Code***

Chapter 75.20 RCW governs construction projects within the waters of the State of Washington. The law requires hydraulic project approvals from the WDFW, Department of Fish and Wildlife for wharves, bulkheads, bridges, culverts, fish habitat restoration projects, and other construction activities within the ordinary high water mark. This regulation helps to protect fish and fish habitat during construction.

### *Regulation of Dairy Farms*

Chapter 90.64 RCW, the Dairy Nutrient Management Act, includes a number of requirements designed to protect water quality from dairy operations. These are in addition to NPDES requirements in the Federal and state Clear Water Acts for concentrated animal feeding operations. The Act requires inspection of all dairy farms, implementation of dairy nutrient management plans, technical assistance and enforcement (including civil penalties) against significant polluters. The intent of the regulation is to protect water quality and, subsequently, fish habitat. The WDOE is the primary regulatory authority under this Act.

### *Other Rules and Regulations*

There are over 100 additional rules and regulations applicable to the protection of water quality and fish habitat in the State of Washington. These rules cover a broad range of subjects such as groundwater quality standards, application of pesticides, well construction, motor oil disposal, utilities, solid waste disposal and recycling, water supply facilities, mining, energy facilities, dikes and levees, aquiculture, etcetera. Lists of applicable laws and rules and links to the specific requirements of those laws and rules can be found at: www.ecy.wa.gov/laws-rules.

## Yakama Reservation Forest Management Plan

The YN has a variety of protective land use regulations in effect on reservation lands. One of these is the FMP. Under the 1993-2002 FMP, the Yakama Administrative Forest was divided into 11 Land Use Management Areas (LUMA). Each LUMA was managed for multiple uses with emphasis on dominant resource features and objectives. The draft FMP soon to be ratified changes the designation of LUMAs to Management Emphasis Areas (MEA), which will be managed within the forest habitat types (BIA and YN 2004). The forestry program is using historical species composition and stand densities as references for the desired future stand conditions. Just as with the health of aquatic systems, forest health describes the ability of a forest ecosystem to remain productive, to maintain a diversity of plants and animals, aesthetic appeal, and resource sustainability, and to withstand disturbances over time. In addition, a healthy forest is resilient to periodic disturbances such as drought, insects, diseases, fires, climatic change, and management practices.

The FMP prescribes the number of miles and density of roads allowed to be built for the purpose of harvesting timber from the Administrative Forest, and forest treatments such as thinning and prescribed burns are being put into place to move the forest vegetation more toward the historical condition of seral stands rather than dense, late successional forest cover. Streams are classified according to their flow, use for domestic purposes and use by fish for spawning, rearing and migration, and buffers and harvest restrictions are set accordingly. The objectives are the preservation of stream bank and riparian cover, water quality and flow maintenance and soil stabilization (BIA and YN 2004).

## Fisheries Management and Evaluation Plan

Recent policy changes will reduce potential harvest impacts. A Fisheries Management and Evaluation Plan (FMEP) for tributary fisheries in the Washington portion of the LCR

Chinook salmon, steelhead, and chum salmon ESUs (WDFW 2002) has been approved by NMFS. WDFW has also requested NMFS approval on a proposed supplement to the FMEP that covers tributary fisheries impacts on listed LCR coho salmon. The agency has also submitted a FMEP for MCR steelhead to NMFS that includes management for recreational fisheries in the White Salmon River. The FMEP minimizes harvest impacts to listed steelhead through the use of selective fisheries that target marked hatchery steelhead and requires the release of all unmarked steelhead. The FMEP also includes management actions that limit impacts to juvenile steelhead through fishing seasons, area closures, and gear restrictions. NMFS is currently reviewing the FMEP to determine if it can be approved under the 4(d) rule limit 4 for MCR steelhead.

### Hatchery and Genetic Management Plans

The USFWS submitted HGMPs to NMFS for approval under section 7 of the ESA. NMFS issued a section 7 Biological Opinion on November 27, 2007 for these hatchery programs (http://www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/Hatcheries/Sec-7-USFWS-Columbia.cfm) (accessed April 19, 2012). . Many actions and measures in the HGMPs have already been implemented. These HGMPs cover programs that release fish into the LWS River and at the Spring Creek NFH. WDFW has also submitted an HGMP to NMFS for the releases of summer and winter steelhead into the White Salmon River. These programs may adversely affect listed populations in the White Salmon River and are being evaluated in a Biological Opinion. All of these programs are funded in whole or partially through the Mitchell Act, which is administered by NMFS. An EIS for NMFS' funding of the Mitchell Act and its hatchery programs is being drafted and will include evaluation of the programs listed above.

## Special Land Use Areas

Several areas in the White Salmon drainage have received special Federal protection**.**

### Columbia River Gorge National Scenic Area

"The National Scenic Area was created to protect and enhance the scenic, natural, cultural and recreational resources of the CR Gorge while encouraging economic development" (www.fs.fed.us/r6/columbia/). The White Salmon River downstream of Condit Dam, RM 3.3-mouth, is within the boundaries of the Gorge National Scenic Area. All new development and land uses must be reviewed in the National Scenic Area to determine if they are consistent with the Act and the implementing land-use ordinances. The development guidelines of the management plan are implemented through land-use ordinances that must be consistent with the management plan.

### Wild and Scenic Rivers

The Wild and Scenic Rivers Act was created by Congress to preserve in a free-flowing condition selected rivers of the nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historical, cultural, or other similar values. The nine-mile reach from confluence of Gilmer Creek near BZ

Corner to Buck Creek is a Federal Wild and Scenic River. A twenty-mile stretch of the upper White Salmon and Cascade Creek received Senate approval for Wild and Scenic designation and awaiting presidential approval. The Act restricts the construction of any dam or other water resource project on or directly affecting a designated river or that would have a direct and adverse effect on the values for which such a river was established, such as its free-flowing nature. The Act directed the Forest Service to develop management plans for these portions. The Wild and Scenic Rivers Act on the White Salmon River does not supersede local Shoreline Management Plans.

## References

BIA (Bureau of Indian Affairs) and YN (Yakama Nation). 2004. Yakama Nation. Draft 2005-2014 Forest Management Plan.

Washington Salmon Recovery Funding Board. 2003. Monitoring and Evaluation Strategy for Habitat Restoration and Acquisition Projects. Draft. Available at: www.rco.wa.gov/doc_pages/other_pubs.shtml (accessed 13 July 2010).

WDFW 2002. Washington State Department of Fish and Wildlife. Salmonid Stock Inventory http://wdfw.wa.gov/fish/sasi/ (accessed April 19, 2012).

# Appendix III. Jewett Creek

Jewett Creek is a small creek located 2 miles to the east of the mouth of the White Salmon River. Geographically, the creek is located within the ICTRT-identified Klickitat independent population spatial distribution boundary, and is, therefore, within the Klickitat River recovery planning area. Jewett Creek is discussed here since it was not considered in the Klickitat Recovery Plan. Any steelhead found in Jewett Creek are most likely hatchery strays or strays from the Klickitat or other independent steelhead populations.

Jewett Creek does not meet the minimum criteria for consideration in the ICTRT's assessment of intrinsic habitat potential (ICTRT 2008) and is not considered a major or minor spawning area for the Klickitat independent population of the MCR Steelhead DPS. The creek does not have sufficient habitat to support a viable population, and the population has not been identified as contributing to the viability of the middle Columbia steelhead DPS (ICTRT 2004).

The lower portion of the creek runs through roughly 100 yards of pipe located under an existing industrial plant. The Bonneville Pool may back up water within the pipe. The creek daylights for approximately 0.9 miles between the railroad and Highway 14, and then passes under the highway. Another 0.8 miles of habitat is available upstream of the Highway. The gradient of the creek becomes impassable at the Gorge bluffs, located at roughly river-mile 0.35.

Local residents have indicated that fish have been seen up to the gorge bluffs. The entire area of stream, which is accessible to anadromous fish, is within the Bingen City limits. No information is available regarding the quality of the 1.7 miles of available habitat; however, monitoring and evaluation actions have been proposed to identify anadromous fish usage and habitat conditions. The ICTRT determined that at least 9.3 miles (15 km) of habitat is necessary to support a viable population of 500 fish (ICTRT 2004).

**References**

ICTRT (Interior Columbia Technical Recovery Team). 2004. Preliminary Guidelines for Population-level Abundance, Productivity, Spatial Structure, and Diversity Supporting Viable Salmonid Populations: An Update. December 13, 2005. Interior Columbia Technical Recovery Team. Northwest Fisheries Science Center. Seattle, Washington.

ICTRT. 2008. Current status reviews: Interior Columbia basin salmon and steelhead ESUs. Volume III: MCR Steelhead DPS. May 2008 Draft.

# Appendix IV. White Salmon River Implementation Schedule: Summary of Actions and Potential Costs to Restore White Salmon River Anadromous Fish Populations and Their Habitat

The following table lists the recovery actions identified by the Washington Gorge Implementation Team to address salmon and steelhead recovery in the White Salmon River watershed. Actions addressing implementation of PacifiCorp's decommissioning plans, restoration of the reaches affected by the former Northwestern Lake and the former Condit Dam, and harvest practices potentially affecting the rate of recovery are priority actions.

**Detailed cost breakdown by specific action.**

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | | | | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|---|---|---|
| | Chinook | Steelhead | Coho | Chum | | | | | | |
| Species Reintroductions | x | x | x | | Restore populations | Implement reintroduction plan for White Salmon salmonids | White Salmon Working Group | $0 | | $0 |
| RM&E | x | x | x | x | Baseline Habitat Data Collection | Gather information needed to identify and prioritize habitat actions that will provide the greatest opportunity to contribute to recovery | PacifCorp, White Salmon Working Group | $131,000 | | $0 |
| | x | x | x | x | Population Monitoring:<br><br>- Monitor population abundance and productivity<br><br>- Monitor proportion and origin of hatchery salmon and steelhead on the spawning grounds | Install & maintain large multiplexing PIT-tag detectors in the lower White Salmon mainstem, & in Buck & lower Rattlesnake Creeks. Report findings. | White Salmon Working Group | $176,000 | | $176,000 |

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|
| | | proportion and origin of hatchery salmon and steelhead on the spawning grounds<br><br>- Assess the resident trout contribution to smolts below Condit Dam; assess change in resident population after steelhead re-colonization/re-introduction | | | | | |
| | | | Implement population monitoring in the White Salmon River & Rattlesnake Creek. | White Salmon Working Group | $300,000 | | $300,000 |
| | | | Install two small stationary in-stream PIT-tag detectors in the lower most portion of Spring Creek. | USGS | $20,000 | | $20,000 |
| | | | Pit-Tag 3,000 juvenile salmonid each year above & below Condit Dam to track individual movement & seasonal growth rates. | USGS | $10,000 | | $10,000 |

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | | | | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Conduct adult spawning ground surveys and monitor. | WDFW | $351,000 | | $351,000 |
| | | | | | | Create and maintain fish counts & biological database. | WDFW | $9,000 | | $9,000 |
| | | | | | | Mark adults for mark-recapture population estimates. | WDFW | $72,000 | | $72,000 |
| | | | | | | Derive estimates of salmonid population abundance & complete reporting | USGS & WDFW | $400,000 | | $400,000 |
| | | | | | Population Monitoring: Genetic analses | Compare adult & smolt genetic analyses to ongoing adult salmon escapement estimates of WDFW & smolt outmigration estimates of USGS studies in the White Salmon River. | USFWS | $70,000 | | $70,000 |
| Habitat | x | x | x | | Restore channel, stabilize banks, replant banks, and restore habitat in inundated area currently occupied by the reservoir and habitats downstream of | Implement PacifiCorp's Decommissioning Management Plans. | PacifiCorp | $895,000 to 1,100,000+ | $895,000 to 1,100,000+ | $0 |

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | | | | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Condit dam impacted by dam removal | Restore channel mainstream above Condit Dam. | YN, WDFW, UCD | $400,000-600,000 | $400,000-600,000 | $0 |
| | | | | | | Restore riparian condition. | UCD | $260,000 | | $260,000 |
| | | | | | | Dredge mouth of River if needed | ACOE | TBA | | TBA |
| | x | x | x | x | Protect and conserve existing natural ecological processes | Protect existing habitat from future degradation though existing regulatory structure | Federal, state, county, and local governments | | | $0 |
| | | | | | | Protect existing habitat from future degradation though land management plans, conservation easements, acquisitions, reclassification of lands as natural areas | UCD, NRCS, Counties, Land Trusts, landowners | $260,000 | $10,000 | $250,000 |

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | | | | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|---|---|---|
| | x | x | x | | Restore vegetation along stream sections that exceed state standards for temperature | Identify stream segments that are excessively warm; within those areas, work with willing landowners to implement actions to increase density of riparian vegetation where sparse; implement programs to protect existing riparian vegetation, reduce sediment inputs to streams. | YN, WDFW, UCD, Mid-Columbia Regional Fishery Enhancement Group (MCRFEG), Klickitat Co. | $260,000 | | $260,000 |
| | | x | x | | Restore passage and connectivity's to habitats blocked or impaired by artificial barriers | In cooperation with irrigation district and others, remove or replace barriers inhibiting upstream passage including dikes, culverts and irrigation structures, provide/upgrade screening of irrigation diversions. | YN, USFWS, WDNR, WDOT, Private landowners, USFS, UCD, or others | $700,000 | | $700,000 |
| | | | | | | Indian Creek culvert replacement. | UCD, USFWS, YN, Counties | $368,000 | $118,000 | $250,000 |
| | x | x | x | x | Reduce nutrient inputs | Reduce runoff of nutrients from septic tanks, dairies, agricultural lands, and other sources. | UCD, WDOE, NRCS, landowners, Counties | $1,111,000 | $10,000 | $450,000 |

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | | | | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|---|---|---|
| | x | x | x | | Improve LWD abundance and recruitment | In cooperation with landowners plan, design and install stable wood and other large debris in steambeds and develop approaches to ensuring long-term LWD recruitment. | UCD, MCRFEG, YN, FS, WDFW, landowners | $715,000 | $0 | $715,000 |
| | | | | | | In cooperation with landowners develop grazing strategies that promote riparian recovery. | UCD, landowners | $80,000 | $0 | $80,000 |
| | | | | | | Eradicate invasive plant species from riparian areas. | County weed control board, USFS, landowners | $120,000 | Unknown | $120,000 |
| | | | | | Restore channel | With willing landowners, stabilize streambanks, restore natural channel form, reduce sediment inputs as needed from roads | UCD, landowners, MCRFEG, YN, USFWS, USFS, WDNR | 80,000-120,000 | $0 | 80,000-120,000 |
| | | | | | Reduce anthropogenic effects on stream flow | Quantify anthropogenic effects on stream flow and identify priority actions | Counties | $200,000 | $0 | $200,000 |
| | | | | | | With willing landowners, Implement water conservation measures | Counties, UCD, WDOE | $1,500,000 | $0 | $1,500,000 |

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | | | | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Improve irrigation conveyance and efficiency | UCD, landowners | $3,500,000 | $0 | $3,500,000 |
| | | | | | | Employ BMPs with willing landowners | Counties, WDFW, YN, USFS, landowners, UCD | $400,000 | $0 | $400,000 |
| | | | | | | Protect/restore springs with willing landowners | Counties, WDFW, YN, USFS, landowners, UCD, MCRFEG | $450,000 | $0 | $450,000 |
| | | | | | | Increase pool habitat | Counties, WDFW, YN, USFS, landowners, MCRFEG | $900,000 | $0 | $900,000 |
| | | | | | | With willing landowners restore wetlands | Counties, WDFW, YN, USFS, landowners, UCD, MCRFEG | $600,000 | $0 | $600,000 |
| | | | | | | Hydrologically disconnect roads from streams. | Counties, WDFW, YN, USFS, landowners | $1,500,000 | $0 | $1,500,000 |

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | | | | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Control road/stream interactions by reducing erosion potential | Counties, WDFW, YN, USFS, landowners | 500,000-700,000 | $0 | 500,000-700,000 |
| | x | x | x | x | Public Awareness | Public Awareness regarding restoration projects and importance of wood in streams and riparian areas | UCD, MCRFEG, WDFW, YN, USFWS, | 30,000 to 40,000 | $0 | 30,000 to 40,000 |
| Harvest | x | x | x | x | Harvest Management | Manage harvest for low impact fisheries and rapid population growth | PFMC, U.S. v. Oregon Parties | TBD | **$0** | **$0** |
| | x | x | x | x | Harvest Management | Adjust tributary harvest regulations in areas where harvest significantly impacts salmon and steelhead population growth | WDFW, YN, Co-managers | $50,000 | **$0** | $0 |
| Hatcheries | x | x | x | x | Reintroduction - hatchery production | Rehabilitate White Salmon Ponds and update intake screen | Co-managers USFWS | $450,000 | **$0** | **$450,000** |
| Hydrosystem and Mainstem Predation | x | x | x | x | Maintain or improve hydropower operations and facilities at Bonneville Dam to enhance salmon and steelhead survival | Decrease water travel time during smolt outmigration | BPA, ACOE | Costs addressed in Middle-Columbia River roll-up plan | | |

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | | | | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|---|---|---|
| Hydrosystem and Mainstem Predation | x | x | x | x | Maintain or improve hydropower operations and facilities at Bonneville Dam to enhance salmon and steelhead survival | Improve operation of adult passage, maintain high standards of adult fish passage at Bonneville Dam | BPA, ACOE | Costs addressed in Middle-Columbia River roll-up plan | | |
| Hydrosystem and Mainstem Predation | x | x | x | x | Reduce predation on salmonids | Reduce predation by pinnipeds, piscivores, cornorants, and Caspian terns | BPA, ACOE | Costs addressed in Middle-Columbia River roll-up plan | | |
| **Jewett Creek** | | | | | | | | | | |
| RM&E | | x | x | | Baseline data collection | Determine spatial distribution of salmonids in Jewett Creek. | MCFEG, YN, WDFW | $1,000 | | |
| RM&E | | x | x | | Baseline data collection | Complete gathering information on existing salmonid stocks: determine the status, life histories and genetic composition of fish in Jewett Creek | MCFEG, YN, WDFW, | $2,000 | | |
| RM&E | | x | x | | Baseline data collection | Assess fish passage and habitat conditions in lower Jewett Creek | MCFEG, YN, WDFW, landowners, | $5,000 | | |

| Recovery Strategies as Prioritized in Recovery Plan | Applicable Species | | | | Action Type | Specific Action(s) | Potential Implementing Entity(s) | Total Estimated Cost ($) | Total Cost Secured | Funds Needed |
|---|---|---|---|---|---|---|---|---|---|---|
| Habitat | | x | x | | | Restore riparian areas based on habitat assessment | MCFEG, YN, WDFW, landowners, | $75,000 | | |
| | | | | | | | | $16,781,000 | $1,873,000 | $13,993,000 |

# Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead

**National Marine Fisheries Service**
**Northwest Region**

January 2011

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
PORTLAND OFFICE
1201 NE Lloyd Boulevard, Suite 1100
PORTLAND, OREGON 97232-1274

NOTE TO READERS:

This *Columbia River Estuary Recovery Plan Module* will be the basis of estuary recovery actions for Endangered Species Act-listed salmon and steelhead in the Columbia River Basin. The module will be incorporated by reference into recovery plans for listed Columbia Basin salmon evolutionarily significant units (ESUs) and steelhead distinct population segments (DPSs). It is important to have a unified set of actions for the Columbia River estuary to address the needs of all listed Columbia Basin ESUs and DPSs.

This *Columbia River Estuary Recovery Plan Module* was prepared for NOAA's National Marine Fisheries Service (NMFS) by the Lower Columbia River Estuary Partnership, (contractor) and PC Trask & Associates, Inc. (subcontractor).

DISCLAIMER:

Recovery plans delineate such reasonable actions as may be necessary, based upon the best scientific and commercial data available, for the conservation and survival of listed species. Plans are published by the National Marine Fisheries Service (NMFS), sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others. Recovery plans do not necessarily represent the views, official positions, or approval of any individual or agencies involved in the plan formulation, other than NMFS. They represent the official position of NMFS only after they have been signed by the Assistant Administrator. Recovery plans are guidance and planning documents only; identification of an action to be implemented by any public or private party does not create a legal obligation beyond existing legal requirements. Nothing in this plan should be construed as a commitment or requirement that any Federal agency obligate or pay funds in any one fiscal year in excess of appropriations made by Congress for that fiscal year in contravention of the Anti-Deficiency Act, 31 U.S.C. 1341, or any other law or regulation. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

LITERATURE CITATION SHOULD READ AS FOLLOWS:
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# Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead

## National Marine Fisheries Service
## Northwest Region

**Prepared for NMFS by the Lower Columbia River Estuary Partnership (contractor) and PC Trask & Associates, Inc. (subcontractor)**

January 2011

# Contents

**Acknowledgements** ..... **vii**
**Acronyms and Abbreviations** ..... **xi**
**Glossary** ..... **xiii**
**Executive Summary** ..... **ES-1**
**1 The Columbia River Estuary and Plume** ..... **1-1**
Purpose and Development of the Estuary Recovery Plan Module ..... 1-1
Formation and Current Characteristics of the Estuary ..... 1-3
Estuary Reaches ..... 1-4
Columbia River Plume ..... 1-8
Major Land Uses ..... 1-8
Two Centuries of Change ..... 1-9
**2 Salmonid Use of the Estuary and Plume** ..... **2-1**
Salmonid Species in the Columbia River Basin ..... 2-1
Life History Types and Strategies ..... 2-2
Changes in Life History Diversity ..... 2-3
Relationship of the Estuary to the Columbia River Basin ..... 2-5
Summary ..... 2-8
**3 Limiting Factors** ..... **3-1**
Determining Estuary Habitat Limiting Factors ..... 3-1
Sources ..... 3-1
Mortality Estimates ..... 3-2
Density-Dependent Mortality ..... 3-3
Habitat-Related Limiting Factors ..... 3-4
Reduced In-Channel Habitat Opportunity ..... 3-5
Reduced Off-Channel Habitat Opportunity ..... 3-6
Reduced Plume Habitat Opportunity ..... 3-8
Limiting Factor: Water Temperature ..... 3-8
Limiting Factor: Stranding ..... 3-10
Food Web-Related Limiting Factors ..... 3-10
Food Source Changes ..... 3-11
Competition and Predation ..... 3-13
Toxic Contaminants ..... 3-15
Limiting Factor: Bioaccumulation Toxicity ..... 3-18
Limiting Factor: Non-Bioaccumulative Toxicity ..... 3-18
Habitat Opportunity, Habitat Quality, and Synergistic Effects ..... 3-21
Prioritization of Limiting Factors ..... 3-22
Summary ..... 3-23
**4 Threats to Salmonids** ..... **4-1**
Flow-Related Threats ..... 4-2
Threat: Climate Cycles and Global Climate Change ..... 4-4
Threat: Water Withdrawal ..... 4-5
Threat: Flow Regulation ..... 4-6

Sediment-Related Threats ..... 4-6
Threat: Entrapment of Fine Sediment in Reservoirs ..... 4-7
Threat: Impaired Transport of Coarse Sediment ..... 4-7
Threat: Dredging ..... 4-7
Structural Threats ..... 4-8
Threat: Pilings and Pile Dike Structures ..... 4-8
Threat: Dikes and Filling ..... 4-9
Threat: Reservoir-Related Temperature Changes ..... 4-10
Threat: Over-Water Structures ..... 4-10
Food Web-Related Threats ..... 4-10
Threat: Reservoir Phytoplankton Production ..... 4-11
Threat: Altered Predator/Prey Relationships ..... 4-11
Threat: Ship Ballast Practices ..... 4-12
Water Quality-Related Threats ..... 4-13
Threat: Agricultural Practices ..... 4-14
Threat: Urban and Industrial Practices ..... 4-14
Other Threats ..... 4-15
Threat: Riparian Practices ..... 4-15
Threat: Ship Wakes ..... 4-16
Prioritization of Threats ..... 4-16
Summary ..... 4-20
**5 Management Actions ..... 5-1**
Identification of Management Actions ..... 5-1
Other Recommended Management Actions ..... 5-4
Evaluation of Management Actions: Constraints to Implementation ..... 5-6
Evaluation of Management Actions: Survival Improvement Targets ..... 5-33
Estimating Juvenile Mortality in the Estuary and Plume ..... 5-33
Establishing Survival Improvement Targets ..... 5-34
Assigning Survival Improvement Targets to Recovery Actions ..... 5-37
Uses of the Survival Improvement Targets ..... 5-38
Evaluation of Management Actions: Costs and Schedule ..... 5-41
Summary ..... 5-68
**6 Research, Monitoring, and Evaluation ..... 6-1**
RME Framework ..... 6-2
Status and Trends Monitoring ..... 6-2
Action Effectiveness Research ..... 6-5
Critical Uncertainties Research ..... 6-6
Implementation and Compliance Monitoring ..... 6-7
Adaptive Management Approach ..... 6-7
Coordination ..... 6-8
Data and Information Management ..... 6-9
Synthesis, Reporting, and Evaluation ..... 6-10
Existing Programs and Projects and Additional Monitoring Needs ..... 6-10
Existing Programs and Projects ..... 6-10
RME Needs, Existing Project Coverage, and Recommended Projects ..... 6-11
Monitoring Recommendations ..... 6-11
Estimated Costs ..... 6-11

Summary ..... 6-11
**7 Perspectives on Implementation ..... 7-1**
Putting the Estuary in Context ..... 7-1
Factors That Influence Decision Making ..... 7-2
Significance of Constraints to Implementation ..... 7-2
Management Actions Offering the Greatest Survival Benefits ..... 7-4
Costs for Constrained Implementation of Management Actions ..... 7-7
Cost-Effectiveness of Management Actions ..... 7-9
Improving Ecosystem Health ..... 7-11
Implementation Issues ..... 7-15
Relationship of the FCRPS BiOp to the Estuary Module ..... 7-15
Preparation for Decision Making ..... 7-16
**8 References ..... 8-1**

**Appendixes**

A Selected Threats to Salmonids by Reach
B Development of Survival Improvement Targets

**Tables**

ES-1 Management Actions to Address Threats ..... ES-7
ES-2 Management Actions Important for Survival of Ocean- and Stream-Type Salmonids ..... ES-10
2-1 Characteristics of Ocean- and Stream-Type Salmonids ..... 2-2
2-2 Life History Strategies and Their Attributes ..... 2-4
2-3 Linkage between Salmonid ESU, Dominant Life History Type, and Life History Strategy ..... 2-5
3-1 Impact of Limiting Factors on Ocean- and Stream-Type Salmonids ..... 3-24
3-2 Limiting Factor Prioritization ..... 3-25
4-1 Linkages Between Limiting Factors and Threats to Ocean- and Stream-Type Salmonids ..... 4-17
4-2 Prioritization of Threats to Ocean- and Stream-Type Salmonids ..... 4-20
5-1 Management Actions to Address Threats ..... 5-2
5-2 Constraints to Implementation of Management Actions ..... 5-8
5-3 Summary of Constraints to Implementation of Management Actions ..... 5-31
5-4 Estimated Mortality Rates, Survival Rates, and Survival Improvement Targets for Wild, ESA-Listed Juveniles ..... 5-35
5-5 Survival Improvement Targets Allocated to Management Actions ..... 5-39
5-6 Estimated Cost and Schedule ..... 5-44
5-7 Summary of Costs of Management Actions ..... 5-67
6-1 Monitoring Plans Applicable to Estuary RME ..... 6-3
6-2 Ongoing Monitoring Programs Applicable to Estuary RME (as of July 2009) ..... 6-13
6-3 Ongoing Projects Addressing Estuary RME (as of July 2009) ..... 6-15
6-4 Management Actions, Associated Monitoring Needs, and Existing Coverage ..... 6-17
6-5 Recommended New RME Projects ..... 6-20
6-6 Monitoring Guidance for Estuary Recovery Plan Module RME ..... 6-21

6-7 Estimated Cost and Schedule ..... 6-27
7-1 Management Actions Sorted by Degree of Constraint ..... 7-3
7-2 Management Actions Sorted by Benefit to Stream-type Juveniles ..... 7-5
7-3 Management Actions Sorted by Benefit to Ocean-type Juveniles ..... 7-6
7-4 Management Actions Sorted by Estimated Cost ..... 7-8
7-5 Management Actions Sorted by Cost/Survival Index ..... 7-10

## Figures

ES-1 Listed Pacific Northwest ESUs ..... ES-2
1-1 The Columbia River Estuary and Its Major Tributaries ..... 1-4
1-2 Lower Columbia River Estuary Reaches ..... 1-5
1-3 Plume Front ..... 1-9
2-1 Historical and Contemporary Early Life History Types of Chinook Salmon in the Columbia River Estuary ..... 2-7
3-1 Diked Areas in the Columbia River Estuary ..... 3-7
3-2 Temperatures of Water Entering the Estuary ..... 3-9
3-3 Conceptual Model of the Columbia River Estuary Food Web ..... 3-12
3-4 Concentrations of PCBs in the Stomach Contents of Subyearling Fall Chinook ..... 3-20
3-5 Concentrations of DDTs in the Stomach Contents of Subyearling Fall Chinook ..... 3-20
3-6 Concentrations of Total Aromatic Hydrocarbons in the Stomach Contents of Subyearling Fall Chinook ..... 3-21
4-1 Conceptual Model of the Columbia River Estuary ..... 4-2
4-2 Changes in the Annual Columbia River Flow ..... 4-3
4-3 Subtidal, Intertidal, and Above-Tidal Estuarine Wetland Zones ..... 4-9
6-1 NMFS Listing Status Decision Framework ..... 6-8

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# Acronyms and Abbreviations

| | |
|---|---|
| BACI | before-after-control-impact |
| BiOp | Biological Opinion |
| BMP | best management practice |
| BMPs | best management practices |
| cfs | cubic feet per second |
| CRE | Columbia River estuary |
| CSMEP | Collaborative Systemwide Monitoring and Evaluation Project |
| DDT | dichlorodiphenyltricholoroethane |
| DEQ | Oregon Department of Environmental Quality |
| DPS | distinct population segment |
| EDT | Ecosystem Diagnosis and Treatment |
| ENSO | El Niño/Southern Oscillation |
| EPA | U.S. Environmental Protection Agency |
| ERME | estuary research, monitoring, and evaluation |
| ESA | Endangered Species Act |
| ESU | evolutionarily significant unit |
| ETM | estuarine turbidity maximum |
| FCRPS | Federal Columbia River Power System |
| GIS | geographic information system |
| HUC | hydrologic unit code |
| ISAP | Independent Science Advisory Panel |
| ISRP | Independent Science Review Panel |
| LCFRB | Lower Columbia Fish Recovery Board |
| LCRANS | Lower Columbia River Aquatic Nonindigenous Species Survey |
| LIDAR | Light Detection and Ranging |
| MMPA | Marine Mammal Protection Act |
| MR&E | monitoring, research, and evaluation |
| NASQAN | National Stream Quality Accounting Network |
| NMFS | National Marine Fisheries Service |
| NOAA | National Oceanic and Atmospheric Administration |
| NPCC | Northwest Power and Conservation Council |
| PAHs | polycyclic aromatic hydrocarbons |
| PCBs | polychlorinated biphenyls |

| | |
|---|---|
| PDO | Pacific Decadel Oscillation |
| PIT | passive integrated transponder |
| PNAMP | Pacific Northwest Aquatic Monitoring Partnership |
| RM | river mile |
| RME | research, monitoring, and evaluation |
| TMDL | total maximum daily load |
| VGP | vessel general permit |
| WDF | Washington Department of Fisheries |
| WDFW | Washington Department of Fish and Wildlife |

# Glossary

**Accretion:** The accumulation of sediment deposited by natural fluid flow processes.

**Alevins**: Salmonids at the life stage between egg and fry.

**Amphipods:** Benthic invertebrates, particularly the amphipod *Americorophium salmonis,* which is found in intertidal and shallow subtidal habitats of the Columbia River estuary and is seasonally important in the diet of juvenile salmonids.

**Ancient marshes:** Marshes formed between 6,000 and 10,000 years ago.

**Bar:** A ridge or succession of ridges of sand or other substances, especially a formation extending across the mouth of a river or harbor that may obstruct navigation.

**Bathymetry**: The measure of the depths of oceans, seas, or other large bodies of water.

**Beach erosion**: The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

**Beach nourishment**: The process of replenishing a beach by artificial means, such as through deposition of dredged materials; also called beach replenishment or beach feeding.

**Bedload:** Sand that rolls and bounces along the surface of the riverbed, usually downstream, although there may be a small displacement toward deeper water caused by the side slopes of the riverbed. In sandy riverbeds, bedload transport shapes the bed into a series of sand waves.

**Beneficial use:** Placement or use of dredged material for some productive purpose. Examples of beneficial uses include habitat development, beach nourishment, aquaculture, parks and recreation, shoreline stabilization, and erosion control.

**Benthic:** Of or relating to the bottom of a body of water.

**Buffer area**: A parcel or strip of land that is designed and designated to permanently remain vegetated in an undisturbed and natural condition to protect an adjacent aquatic or wetland site from upland impacts, to provide habitat for wildlife.

**Centennial marshes:** Marshes formed over the last century.

**Continental shelf**: The zone bordering a continent extending from the line of permanent immersion to the depth (usually about 100 to 200 meters) at which there is a marked or steep descent toward greater depths.

**Delta**: An alluvial deposit, usually triangular, at the mouth of a river. It is normally built up only where there is no tidal or current action capable of removing the sediment as fast as it is deposited.

**Deposition:** The deposit of sediment in an area through natural means, such as wave action or currents, or mechanical means.

**Detritus**: A loose mixture of organic material (dead plants and animals) and inorganic material (rock fragments) that results directly from disintegration of the material.

**Dikes**: Earthen walls constructed to contain water; sometimes constructed around dredged material disposal sites but more commonly constructed as flood protection.

**Dredging**: The removal or redistribution of sediments from a watercourse.

**Ecosystem**: A community of organisms in a given area together with their physical environment and its characteristic climate.

**El Niño/Southern Oscillation**: A shorter term climate effect that alternates between cold and warm phases approximately every 3 to 7 years; is associated with a warm-water current that periodically flows southward along the coast of Ecuador, and the southern oscillation

in the atmosphere; affects climatic and ocean conditions throughout the Pacific region.

**Emergent marsh**: A wet, springy peatland that occurs along the edges of lakes and streams and is covered by grass-like sedges and fed by minerals washing in from surrounding lands.

**Emergent vegetation:** Rooted plants that can tolerate some inundation by water and that extend photosynthesis parts above the water surface for at least part of the year; emergent vegetation is intolerant of complete inundation over prolonged periods.

**Estuarine turbidity maximum (ETM**): A circulation phenomenon in an estuary that traps particles and promotes biochemical, microbial, and ecological processes that sustain an important pathway in the estuary's food web.

**Estuary**: A semi-enclosed coastal body of water with a free connection to the open ocean in which sea water is diluted with runoff from the land.

**Exotic species**: A non-native plant or animal deliberately or accidentally introduced into a habitat.

**Fill:** Sand, sediment, or other earth materials that are placed, deposited, or stockpiled.

**Fingerling**: A juvenile salmonid less than 1 year old.

**Floodplain**: A flat tract of land bordering a river, mainly in its lower reaches, and consisting of alluvium deposited by the river during flooding.

**Fluvial**: Involving running water; usually pertains to stream processes.

**Forested wetlands**: Wetlands that occur in palustrine and estuarine areas and possess an over story of trees, an understory of young trees or shrubs, and a herbaceous layer.

**Freshet**: High stream flow caused by rains or snowmelt and resulting in the sudden influx of a large volume of freshwater in the estuary.

**Fresh water:** Water that is less than 0.5 part salt per thousand.

**Fry**: Juvenile salmonids that have absorbed their egg sac.

**Genetic diversity**: Variation at the level of individual genes (polymorphism); provides a mechanism for populations to adapt to their ever-changing environment.

**Habitat**: The physical, biological, and chemical characteristics of a specific unit of the environment occupied by a specific plant or animal; the place where an organism naturally lives.

**Habitat capacity**: A category of habitat assessment metrics, including "habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality" (Fresh et al. 2005).

**Habitat connectivity**: A measure of how connected or spatially continuous habitats occur in a larger ecosystem.

**Habitat opportunity**: A category of habitat assessment metrics that evaluate the capability of juvenile salmon to access and benefit from the habitat's capacity (Fresh et al. 2005).

**High marsh:** A wetland ecosystem influenced by a marsh surface elevation at approximately mean higher high water that is inundated by only the most extreme high tides and is characterized by salt-tolerant emergent vegetation.

**Intertidal:** Of or relating to the substrate that is exposed and flooded by tides; includes the associated splash zone.

**In-water disposal:** Placement of dredged material along the riverbed in or adjacent to the navigational channel or in designated in-water sites; commonly referred to as flow-lane disposal.

**Limiting factor**: Physical, chemical, or biological features that impede species and their independent populations from reaching viability status.

**Littoral**: Of, relating to, or situated or growing on or near a shore; especially of the sea.

**Littoral current**: A current running parallel to the beach and generally caused by waves striking the shore at an angle.

**Low marsh:** A wetland ecosystem characterized by salt-tolerant emergent vegetation and twice-daily inundation of high tides.

**Macroinvertebrates:** Invertebrates that are of visible size, such as clams and worms.

**Marsh:** An area of soft, wet, or periodically inundated land, generally treeless and usually characterized by grasses and other low growth.

**Mean high water:** The average height of all high waters over 19 years.

**Mean higher high water:** The average height of the higher of two unequal daily high tides over 19 years.

**Mean low water:** The average height of all low waters over 19 years.

**Mean lower low water:** The average height of the lower of two unequal daily low tides over 19 years.

**Macrodetritus**: Dead or dying matter from a plant or animal that is visible to the unaided eye; usually larger than 1 to 2 mm in diameter.

**Microdetritus**: Dead or dying matter from a plant or animal; usually smaller than 1 to 2 mm in diameter.

**Navigational channels**: Channels in estuaries and other water bodies that are created, deepened, and maintained by dredging to enable vessels to navigate safely between, into and out of ports, harbors, and marinas without running aground.

**Nearshore**: An indefinite zone extending seaward from the shoreline well beyond the breaker zone.

**Ocean-type**: Of or relating to salmonid juveniles that enter the estuary as fry or fingerlings and stay in the estuary for weeks or months before entering the ocean; examples are chum and subyearling Chinook.

**Oligohaline:** Of or relating to water having low salinity.

**Overbank flooding**: Out-of-bank flooding resulting from flow events that exceed the bankfull.

**Over-water structures:** Human-made structures, such as a pier, that extend over all or part of the surface of a body of water.

**Pacific Decadal Oscillation**: A longer term climate effect that alternates between cold and warm phases approximately every 30 years.

**Pelagic**: Pertaining to the open ocean.

**Pinnipeds**: Seals, sea lions, and walruses that belong to the taxonomic suborder called Pinnipedia, or the "fin-footed." Pinnipeds are carnivorous aquatic mammals that use flippers for movement on land and in the water. The pinnipeds referred to in this document are Pacific harbor seals, California sea lions, and Stellar sea lions.

**Pier**: A structure, usually of open construction, extending out into the water from the shore, to serve as a landing place, recreational facility, etc., rather than to afford coastal protection.

**Piling:** A long, heavy timber or section of concrete or metal that is driven into the earth or bottom of a water body to serve as a structural support or protection.

**Pile dike:** Two parallel rows of piling that are tied together and extend 300 to 500 feet into the river.

**Pile dike field:** Several pile dikes spaced about 1,200 to 1,500 feet apart, typically built to concentrate flow and stabilize the channel; within the dike field, current velocities are slowed and flow is deflected away from the river bank.

**Plume**: The layer of Columbia River water in the nearshore Pacific Ocean.

**Polychlorinated biphenyls (PCBs):** A group of synthetic, toxic industrial chemical compounds that are chemically inert and not biodegradable; they once were used in making paint and electrical transformers.

**Polycyclic aromatic hydrocarbons (PAHs):** A group of more than 100 different chemicals that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat.

**Population**: A distinct breeding unit of a species that exhibits similar life history strategies.

**Redds**: Spawning nests used by trout and salmon.

**Revetment**: A facing of stone, concrete, etc., to protect an embankment or shore structure from erosion by wave action or currents.

**Salmonid**: Any member of the family Salmonidae, which includes the salmon, trout, char, whitefishes, and grayling of North America.

**Salmonid population viability**: Measure of the status of anadromous salmonids that uses four performance criteria: abundance, productivity, spatial distribution, and diversity.

**Sand**: An unconsolidated mixture of inorganic soil (possibly including disintegrated shells and coral) consisting of small but easily distinguishable grains ranging in size from about 0.062 mm to 2.0 mm.

**Sand waves:** Waves of sand on the bottom of a riverbed that move in response to river discharge and bedload transport. In the Columbia, sand waves cover the riverbed and are typically 4 to 8 feet high and 300 to 400 feet long. When the river discharge is less than 300,000 cfs, sand waves move only a few feet per day; however, when discharge exceeds 400,000 cfs, sand wave movement can reach 20 feet per day or more.

**Scour:** The removal of underwater material by waves and currents, especially at the base or toe of a structure.

**Sediment**: Material in suspension in water or recently deposited from suspension; in the plural, all kinds of deposits from the waters of streams, lakes, or seas.

**Sediment trapping:** The capture of sediments behind structures such as dams and shoreline armoring, which restrict sediments from entering systems.

**Shallows and flats:** Areas from the 6-foot bathymetric contour line up to the edge of tidal marsh or swamp vegetation, or to mean higher high water where vegetation is absent.

**Shoaling:** A gradual decrease in water depth as the result of the accretion of sediments.

**Smolts**: Juvenile salmonids that have left their natal stream and are headed downriver toward the ocean.

**Stream-type**: Of or relating to salmonid juveniles that rear in freshwater for a year or more before entering the ocean.

**Threat**: A human action or natural event that causes or contributes to limiting factors; threats may be caused by past, present, or future actions or events.

**Tidal marshes:** Areas dominated by emergent vegetation and low shrubs; are typically found from mean lower low water to slightly above mean higher high water, although they are rare at the lowest elevations.

**Tidal prism:** The difference in the volume of water covering an area, such as a wetland, during low tide and the volume covering it during the subsequent high tide.

**Tidal swamps:** Shrub- and forest-dominated wetlands that extend up to the line of non-aquatic vegetation (the line at which excess water ceases to be a factor controlling the composition of the vegetation); tidal swamps may be of sufficiently high elevation that they are inundated only during spring tides, but they may also extend down below mean higher high water.

**Tide**: The periodic rising and falling of the water that results from gravitational attraction of the moon and sun acting on the rotating earth.

**Turbidity**: A condition in bodies of water where high sediment loads cause clouding of the water to varying extents; turbidity is an optical phenomenon and does not necessarily

have a direct linear relationship to particulate concentration.

**Viable salmonid population:** An independent population of Pacific salmon or steelhead trout that has a negligible (generally ≤5 percent) risk of extinction over a 100-year timeframe.

# Executive Summary

## What is the Estuary Recovery Module?

This estuary recovery plan module is one element of a larger regional planning effort to develop recovery plans for Endangered Species Act-listed salmon and steelhead trout in the Columbia River basin. Recovery plans are being developed for each of the 13 listed evolutionarily significant units (ESUs) in the Columbia.[1] Figure ES-1 shows the 13 listed ESUs in the Columbia River basin grouped by region. The regions include the Lower Columbia, Upper Willamette, Middle Columbia, Snake, and Upper Columbia River ESUs. Within each of the regions, the ESUs have unique geographical boundaries that are based on similarities among populations.

This estuary recovery plan module complements other recovery plans in the region. The planning area for the module is all tidally influenced areas of the Columbia River. The upstream boundary of this area is Bonneville Dam, at River Mile 146, and the downstream boundary includes the Columbia River plume.[2] With few exceptions, the module's focus is limited to habitat conditions and processes in the Columbia River estuary and plume, rather than hatchery or harvest practices, hydroelectricity production, or tributary habitats in the Columbia River basin. The goal of the module is to identify and prioritize management actions that, if implemented, would reduce the impacts of limiting factors, meaning the physical, biological, or chemical conditions that impede salmon and steelhead survival during their migration through and rearing in the estuary and plume ecosystems. To accomplish this, changes in the physical, biological, or chemical conditions in the estuary are reviewed for their potential to affect salmon and steelhead. Then, the underlying causes of limiting factors are identified and prioritized based on the significance of the limiting factor and each cause's contribution to one or more limiting factors. These causes are referred to as threats and can be either human or environmental in origin. Finally, management actions are identified that are intended to reduce the threats and increase the survival potential of salmon and steelhead during estuarine rearing and migration. Costs are developed for each of the actions using an estimated level of effort to implement actions.

This estuary recovery plan module is intended to help answer questions about the degree to which the estuary and plume can contribute to salmon and steelhead recovery efforts throughout the Columbia River basin. The state of the science surrounding the estuary and plume is such that quantitative answers to questions about estuarine ecology are not necessarily available at this time. This is true in part because of the complexity of the ecological processes in the estuary and plume. However, it is also true because the Columbia River estuary and plume are only now being studied at a level of detail that

[1] NOAA's National Marine Fisheries Service (NMFS) has revised its species determinations for West Coast steelhead under the Endangered Species Act (ESA), delineating steelhead-only "distinct population segments" (DPSs). The former steelhead ESUs included both anadromous steelhead trout and resident, non-anadromous rainbow trout, but NMFS listed only the anadromous steelhead. The steelhead DPS does not include rainbow trout, which are under the jurisdiction of the U.S. Fish and Wildlife Service. In January 2006, NMFS listed five Columbia River basin steelhead DPSs as threatened (71 FR 834). To avoid confusion, references to ESUs in this estuary recovery plan module imply the steelhead DPSs as well.

[2] See Figures 1-1 and 1-2 for a depiction of the planning area.

allows knowledge about this portion of the Columbia River ecosystem to be integrated into the understanding of life history patterns that have been well documented in the upstream portions of the basin.

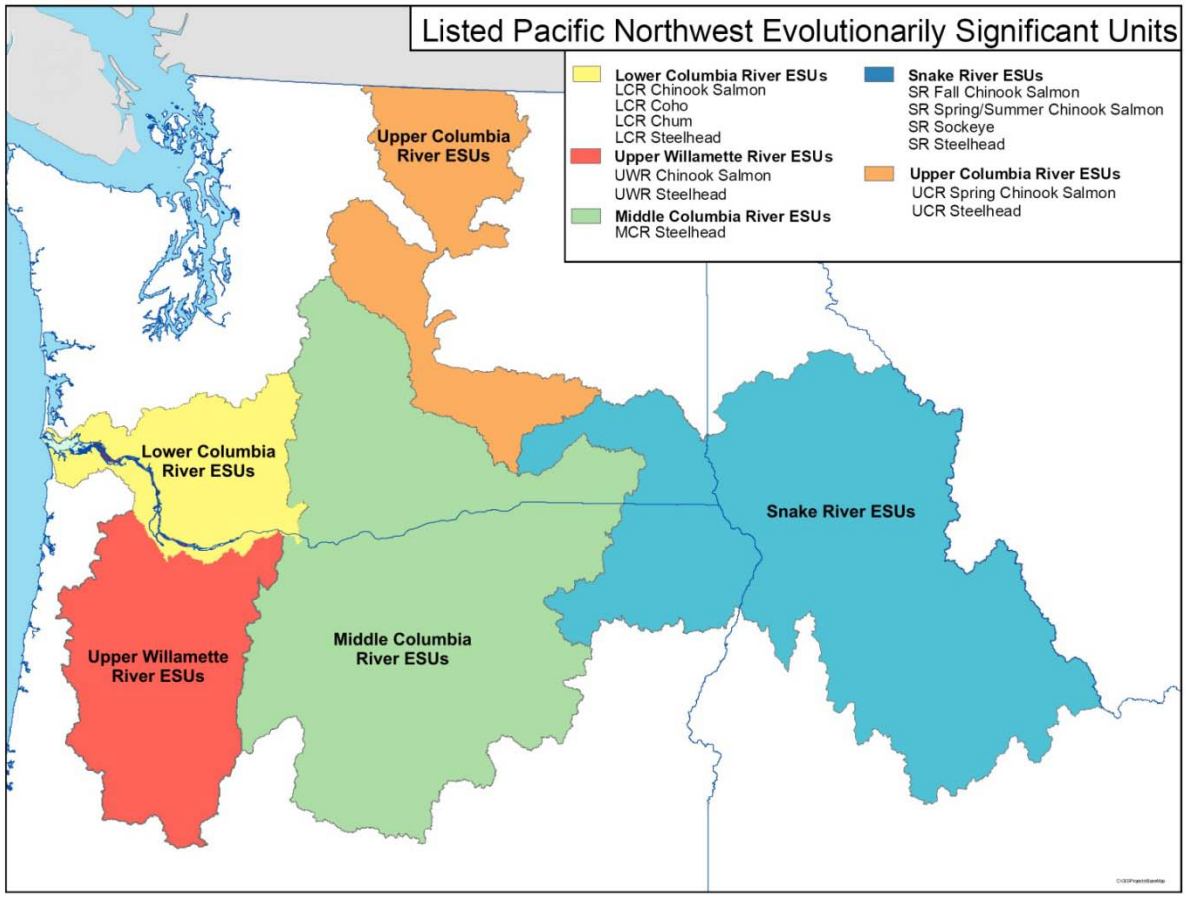


FIGURE ES-1
Listed Pacific Northwest ESUs

This estuary recovery plan module is a synthesis of diverse literature sources and the direct input of estuary scientists. The module was developed by the Lower Columbia Estuary Partnership and a private consultant, PC Trask & Associates, Inc. The primary author was PC Trask & Associates, Inc., with significant involvement from Lower Columbia River Estuary Partnership staff. The author used several key documents as a platform for the module. One of those documents is the "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan," which the Lower Columbia River Estuary Partnership developed, along with its supplement, for the Northwest Power and Conservation Council's *Columbia River Basin Fish and Wildlife Program* (Northwest Power and Conservation Council 2004). In 2005, the Northwest Fisheries Science Center of NOAA's National Marine Fisheries Service (NMFS) produced two important technical memoranda for the estuary: *Salmon at River's End* (Bottom et al. 2005) and *Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead* (Fresh et al. 2005). The author used these two memoranda extensively and consulted other sources as well, including many primary sources. Area experts from the

NMFS Northwest Fisheries Science Center and Northwest Regional Office, the Lower Columbia River Estuary Partnership, and the Lower Columbia Fish Recovery Board provided input and advice on scoring and evaluation processes. Additionally, the author briefed the Northwest Power and Conservation Council, Mid-Columbia Sounding Board, Upper Willamette Recovery Planning Stakeholder Team, and Lower Columbia River Recovery Planning Stakeholder Team and took their feedback into account when refining the module. Lastly, PC Trask & Associates, Inc., and Lower Columbia River Estuary Partnership staff worked with NMFS Northwest Regional Office staff to revise the module in response to comments received during the public comment period.

## Why Are the Estuary and Plume Important?

The Columbia River estuary and plume represent one of three major stages in the life cycle of salmon and steelhead. In tributaries, adults spawn and juveniles rear in freshwater. In the ocean, juveniles grow to adults as they forage in food-rich environments. The estuary is where juveniles and adults undergo vast physiological changes needed to transition to and from saltwater. In addition, a properly functioning estuary provides high growth opportunities and refugia from predators.

But why are the estuary and plume so important? The answer lies in the very reason that salmonids grew in numbers to an estimated 16 million over the past 4,000 years. Salmon and steelhead were successful because they exploited a wide array of the habitat niches available to them. They did this by employing a variety of strategies that allowed them to use many diverse habitats across a wide geographic space. In fact, the distribution of salmon and steelhead historically spanned thousands of river miles throughout the basin.

If this were not remarkable enough, salmon and steelhead's traits allowed them to use habitats at varying times, and this is one of the primary reasons the estuary and plume are so important. Every downstream-migrating juvenile salmon or steelhead must use the habitats of the estuary to complete its life cycle. If the progeny of the 16 million adult salmon and steelhead that historically made use of the estuary had converged on the estuary at one time, there likely would not have been enough habitat and food to sustain them. So they developed strategies to enter the estuary at different times, at different sizes, using unique habitats. In fact, it has been hypothesized that each individual population's use of estuarine habitats is discrete in terms of time and location of use. The implication of this for the estuary and plume today is that the area's habitats must be available through time and space and at sufficient quantities to support more than 150 distinct salmon and steelhead populations, which represent 13 ESUs that use many diverse life history strategies.

The number of adult salmon and steelhead that return to the Columbia River basin each year varies, but in recent years, average returns have been about 1.7 million, with approximately 65 to 75 percent of those fish being of hatchery origin.[3] For 2006, scientists from the NMFS Northwest Fisheries Science Center estimated that about 168 million juveniles would enter the estuary (Ferguson 2006b). This suggests that only 1 percent of the juveniles entering the estuary will return as adults and 99 percent are lost as a result of all the limiting factors (human and natural) in the estuary, plume, nearshore, and ocean.

[3] This is an informal estimate; determining the ratio of hatchery-origin fish with more certainty would require stock-by-stock run calculations averaged over many years.

Understanding the extent to which the estuary and plume contribute to these losses is essential to the ultimate recovery of salmon and steelhead ESUs throughout the basin.

# What Is the Condition of the Estuary Now?

## Flows, Dikes and Filling, and Sediment

The estuary and plume are considerably degraded compared to 200 years ago. In terms of absolute size, the estuary tidal prism is about 20 percent smaller than it was when Lewis and Clark camped along the Columbia's shore (Northwest Power and Conservation Council 2004). This reduction in estuary size is due mostly to dike and filling practices used to convert the floodplain to agricultural, industrial, commercial, and residential uses. Instream flows entering the estuary also have changed dramatically—there has been a 44 percent decrease in spring freshets or floods, and the annual timing, magnitude, and duration of flows no longer resemble those that historically occurred in the Columbia River (Jay and Kukulka 2003). Changes to flow volume and timing are attributed to hydrosystem regulation; water withdrawal for agricultural, municipal, and industrial purposes; and climate fluctuations. Further alterations in flow are likely to occur during the next century as a result of global climate change, the effects of which are expected to include more precipitation falling as rain rather than snow, less snow storage, and—in the estuary—higher peak flows and reduced late-summer/early-fall stream flows (Independent Scientific Advisory Board 2007).

Flow alterations and dike and filling practices are significant to salmon and steelhead in several ways. Historically, vegetated wetlands within the floodplain supplied the estuary with its base-level food source: macrodetritus. The near elimination of overbank events and the separation of the river from its floodplain have altered the food web by reducing macrodetrital inputs by approximately 84 percent (Bottom et al. 2005). At the same time, phytoplankton detrital sources from upstream reservoirs now dominate the base of the food chain. The substitution of food sources likely has profound effects on the estuary ecosystem. In addition, access to and use of floodplain habitats by ocean-type ESUs (salmonids that typically rear for a shorter time in tributaries and a longer time in the estuary) have been severely compromised through alterations in the presence and availability of these critical habitats.

The timing, magnitude, and duration of flows also have important ramifications to in-channel habitat availability and connectivity. Sand transport along the river bottom is highly correlated to flow. With reductions in the magnitude and duration of flows, erosion and accretion processes no longer function as they have for thousands of years. This may have far-reaching consequences to the estuary, plume, and nearshore lands north and south of the river's mouth. At the same time, upstream dams have prevented sediments from entering the estuary, while dredging activities have exported sand and gravel out of the estuary. Studies have shown that sand is exported from the estuary at a rate three times higher than that at which it enters the estuary. The full impact of these changes is unknown; however, sediment transport is a primary habitat-shaping force that determines the type, location, and availability of habitats distributed in the estuary and plume. In addition, decreases in sediments have improved water clarity and increased the effectiveness of predators that consume juvenile and adult salmon and steelhead.

## Water Quality

Water quality in the estuary and plume has been degraded by human practices from within the estuary and also from upstream sources. Today, elevated water temperatures and toxic contaminants both pose risks to salmon and steelhead in the estuary. Summer water temperatures entering the estuary are on average 4° F (2.2° C) warmer today than they were in 1938 (Lower Columbia Fish Recovery Board 2004). The upper thermal tolerance range for cold-water fish, including salmon and steelhead, is about 20° to 24° Celsius (68° to 75° Fahrenheit). Temperatures exceeding this threshold have been occurring earlier in the year and more frequently since 1938 (as measured at Bonneville Dam). Degradation of tributary riparian habitat caused by forest, residential, commercial, and industrial practices, as well as reservoir heating and global climate change are responsible for increased temperatures. During the next century, it is likely that the expected effects of global climate change will continue to increase water temperatures.

Another important indicator of water quality degradation in the estuary is the presence of toxic contaminants. One study of contaminant impacts on juvenile salmon estimated disease-induced mortalities of 1.5 and 9 percent as a result of contaminant stressors for residencies in the Columbia River estuary of 30 to 120 days, respectively (Loge et al. 2005). If this estimate is accurate, threats from contaminants may exceed those from Caspian tern predation.

Toxic contaminants are widespread in the estuary, both geographically and in the food chain, with the urban and industrial portions of the estuary contributing significantly to juvenile salmon's toxic load (Lower Columbia River Estuary Partnership 2007). Some of these contaminants are water-soluble agricultural pesticides and fertilizers, such as simazine, atrazine, and diazinon. Industrial contaminants include polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs). Also present are pharmaceuticals, personal care products, brominated fire retardants, and other emerging contaminants. Concentrations of toxic contaminants in the bodies of juvenile salmonids in the estuary sometimes are above levels estimated to cause health effects. In a 2007 study, this was the case for PCBs, PAHs, and DDT, and juveniles showed evidence of exposure to hormone-disrupting compounds (Lower Columbia River Estuary Partnership 2007). Salmon and steelhead experience both short-term exposure to toxic substances and long-term exposure to contaminants that accumulate over time and magnify through the food chain. Even when exposures are sublethal, they can cause significant developmental, behavioral, health, and reproductive impairments. Ocean-type ESUs are more susceptible to bioaccumulation than stream-type ESUs; however, both are equally vulnerable to acute exposures (stream-type ESUs are those ESUs that typically spend longer periods in tributaries and less time in the estuary).

## Food Web and Species Interactions

The Columbia River estuary represents a distinct ecosystem that is a unique expression of biological and physical interactions. As physical and biological changes occur in the estuary, the ecosystem responds to those changes. There is general agreement that the estuary ecosystem is degraded and no longer provides the same level of support to native species assemblages that it did historically. Unfortunately, this field of research is perhaps the least understood, and its impact on salmon and steelhead is not well documented or studied.

Limiting factors related to the food web and species interactions can be thought of as the product of all the threats to salmon and steelhead in the estuary. Some examples of food web and species interactions-related limiting factors are easy to understand, but others are subtle and far-reaching. Caspian terns are a good example of an ecosystem shift that is easy to understand. New islands formed through the disposal of dredged materials attracted terns away from their traditional habitats, which may be being degraded. Reduced sediment in the river may have increased terns' efficiency in capturing steelhead juveniles migrating to saltwater at the same time that the birds need additional food for their broods. The result is a predator/prey shift in the estuary that has increased mortality for steelhead juveniles. Double-crested cormorants also prey on juvenile salmonids, in similar numbers as terns.

Other shifts in the ecosystem are more complex, and it can be difficult to understand whether or how they affect salmon and steelhead. For example, the shift in the food base of the estuary—from local macrodetrital sources to imported microdetrital sources such as phytoplankton—has fundamentally changed the food web and species relationships; however, what this means to salmon and steelhead—or, for that matter, to the entire estuarine ecosystem—is unknown. The introduction of exotic species is another poorly understood ecosystem alteration. Examples of exotic species thriving in the estuary include 21 new invertebrates, such as Asian clams and copepods, plant species such as Eurasian water milfoil, and exotic fish such as shad. Shad in particular, because of the sheer tonnage of their biomass, undoubtedly play a large role in the degradation of the estuary ecosystem and may compete with juvenile salmonids for food resources. Natural-origin juvenile salmonids may compete with large pulses of hatchery fish for food and space in the estuary if they overlap in space and time. Given the decreases in habitat opportunity and capacity in the estuary, it may be that too many fish—both salmonids and other species—are competing for too few estuarine resources at key times, with the resulting stressors translating into reduced salmonid survival. It is likely that this density-dependent mortality is manifesting itself in the estuary through limiting factors such as reduced off-channel habitat availability, competition with other fish species, and predation by fish and birds.

## Other Threats

The estuary also is influenced by a number of physical structures that contribute to its overall degradation, but the extent of their impacts to salmon and steelhead is poorly understood. Over-water and instream structures in the estuary number in the thousands and alter river circulation patterns, sediment deposition, and light penetration; they also form microhabitats that often benefit predators. In some cases, structures reduce juvenile access to low-velocity habitats. Examples of structures include jetties, pilings, pile dikes, rafts, docks, breakwaters, bulkheads, revetments, groins, and ramps.

Ship wake stranding is an example of another threat to salmon and steelhead in the estuary. A study in 1977 by the Washington Department of Fisheries estimated that more than 150,000 juvenile salmonids, mostly Chinook, were stranded on five test sites as a result of ship bow waves striking shorelines (Bauersfeld 1977). Additional studies since the Bauersfeld study have not documented the same level of mortality. Light Detection and Radar (LIDAR) analysis and results from a new study by the University of Washington and the Portland District of the U.S. Army Corps of Engineers may help characterize this threat in the near future. This threat is most detrimental to ocean-type juvenile fry that are less than 60 millimeters long and that rear inches from shore.

# What Can We Do to Improve Salmon and Steelhead Survival?

## Identification of Management Actions and Monitoring Activities

This estuary recovery module identifies 23 management actions to improve the survival of salmon and steelhead migrating through and rearing in the estuary and plume environments. Table ES-1 lists these management actions and shows their relationship to threats to salmonid survival; this information is presented by topic, rather than priority.

TABLE ES-1
Management Actions to Address Threats

| | Threat | Management Action |
|---|---|---|
| **Flow-related threats** | Climate cycles and global climate change[2] | **CRE[1]-1:** Protect intact riparian areas in the estuary and restore riparian areas that are degraded.[2]<br>**CRE-2:** Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.[2]<br>**CRE-3:** Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries.[2] |
| | Water withdrawal | ***CRE-3:*** *Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries* |
| | Flow regulation | **CRE-4**: Adjust the timing, magnitude, and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume.<br>***CRE-3:*** *Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries.* |
| **Sediment-related threats** | Entrapment of fine sediment in reservoirs | **CRE-5:** Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume. |
| | Impaired transport of coarse sediment | **CRE-6:** Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.<br>**CRE-8:** Remove or modify pilings and pile dikes with low economic value when removal or modification would benefit juvenile salmonids and improve ecosystem health.<br>***CRE-4:*** *Adjust the timing, magnitude, and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume.* |
| | Dredging | **CRE-7:** Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary. |

[1] CRE = Columbia River estuary.

[2] Study of the impacts of global climate change is an evolving field, and additional research is needed to understand the phenomenon's likely effects on estuarine habitats and processes with specificity. At this time, the Independent Scientific Advisory Board of the Northwest Power and Conservation Council expects that the regional effects of global climate change in the next century will include more precipitation falling as rain rather than snow, reduced snow pack, and late-summer/early-fall stream flows, and associated rises in stream temperature (Independent Scientific Advisory Board 2007). The climate-related management actions in Table ES-1 reflect these expected impacts. Although the management actions clearly would not change the threat of global climate change itself, they have the potential to lessen its impact on salmonids in the estuary. Even if climate cycles and global climate change have effects different from those assumed in this document, the management actions that Table ES-1 associates with climate would provide benefits to salmonids by addressing other threats, such as water withdrawal, urban and industrial practices, and reservoir heating. All three of the management actions associated with climate in Table ES-1 are associated with other threats listed in Table ES-1.

Note: Italics indicate an action's second occurrence in the table, in connection with a different threat.

| Threat | | Management Action |
|---|---|---|
| **Structural threats** | Pilings and pile dike structures | ***CRE-8:*** *Remove or modify pilings and pile dikes with low economic value when removal or modification would benefit juvenile salmonids and improve ecosystem health.* |
| | Dikes and filling | **CRE-9:** Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat.<br>**CRE-10:** Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats. |
| | Reservoir-related temperature changes | ***CRE-2:*** *Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.* |
| | Over-water structures | **CRE-11:** Reduce the square footage of over-water structures in the estuary. |
| **Food web-related threats** | Increased phytoplankton production | ***CRE-10:*** *Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats.* |
| | Altered predator/prey relationships | **CRE-13:** Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids.<br>**CRE-14:** Identify and implement actions to reduce salmonid predation by pinnipeds.<br>**CRE-15:** Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of invasive plants.<br>**CRE-16:** Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.<br>**CRE-17:** Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.<br>**CRE-18:** Reduce the abundance of shad in the estuary.<br>***CRE-8:*** *Remove or modify pilings and pile dikes with low economic value when removal or modification would benefit juvenile salmonids and improve ecosystem health.* |
| | Ship ballast practices | **CRE-19:** Prevent new introductions of aquatic invertebrates and reduce the effects of existing infestations<br>***CRE-7:*** *Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary.* |
| **Water quality-related threats** | Agricultural practices | **CRE-20:** Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary.[3]<br>***CRE-1:*** *Protect intact riparian areas in the estuary and restore riparian areas that are degraded.*<br>***CRE-9:*** *Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat.* |
| | Urban and industrial practices | **CRE-21:** Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants.<br>**CRE-22:** Restore or mitigate contaminated sites.<br>**CRE-23:** Implement stormwater best management practices in cities and towns.[3]<br>***CRE-1:*** *Protect intact riparian areas in the estuary and restore riparian areas that are degraded.*<br>***CRE-9:*** *Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat.* |
| **Other threats** | Riparian practices | ***CRE-1:*** *Protect intact riparian areas in the estuary and restore riparian areas that are degraded.* |
| | Ship wakes | **CRE-12:** Reduce the effects of vessel wake stranding in the estuary. |

[3] Unless otherwise noted, the term *best management practices* is used in this document to indicate general methods or techniques found to be most effective in achieving an objective. NMFS envisions that in implementation, specific best management practices would be developed or recommended.

Research, monitoring, and evaluation (RME) needs related to the 23 management actions are discussed in Chapter 6. As noted there, some of these needs are addressed in an existing document, *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program* (Johnson et al. 2008), while others are identified as new needs specific to the management actions in the module. Together, the existing and new RME activities will provide crucial information on salmonid performance in the estuary, the effectiveness of actions that are implemented in the estuary, associated changes in the ecology of the estuary, and scientific uncertainties that affect implementation of the actions.

## Evaluating Management Actions: Relationship of Implementation Constraints to Cost and Survival Improvements

Identifying management actions that could reduce threats to salmon and steelhead as they rear in or migrate through the estuary is an important step toward improving conditions for salmonids during a critical stage in their life cycles. However, actual implementation of management actions is constrained by a variety of factors, such as technical, economic, public health and safety, and property rights considerations. In fact, in some cases it will be impossible to realize an action's full potential because its implementation is constrained by past societal decisions that are functionally irreversible. For example, reclaiming off-channel habitats in the lower Cowlitz River floodplain is constrained by the development of the city of Longview decades ago. An important assumption of the estuary recovery plan module is that the implementation of each of the 23 management actions identified in the module is constrained in some manner.

The module makes another important assumption about implementation: although implementation of actions is constrained, even constrained implementation can make important contributions to the survival of salmonids in the estuary and plume.

It is within the context of these two fundamental assumptions that recovery actions are evaluated in the module, in terms of their costs and potential benefits. The evaluation of survival benefits and costs is highly uncertain because it relies on estimates not only of what is technically feasible, but also of what is socially and politically practical. To help characterize survival improvements, the estuary recovery module uses a planning exercise that involves distributing a plausible survival target across the actions to hypothesize a potential amount of improvement that would result from each action. Costs then are developed by identifying projects for each action and units and per-unit costs for each project. Both the survival improvements and costs reflect assumptions about the constraints to implementation and the degree to which those constraints can be reduced given the technical, social, and political context in the Columbia River basin.

## Evaluation Results

The estuary recovery plan module estimates the cost of constrained implementation of all 23 actions over a 25-year time period at $528.05 million. This represents an order-of-magnitude increase over the current level of investment in the estuary and reflects a significant level of effort needed to improve ecosystem health in the estuary and plume over the next 25 years. An additional $64.1 million is identified in Chapter 6 for research, monitoring, and evaluation activities. This effort is necessary because (1) scientific understanding of the estuary and how salmonids respond to conditions there is not yet

mature, and (2) the module proposes some innovative management actions whose effectiveness should be explored before they are fully implemented. Thus the total implementation costs for the module are $592.15 million.

Table ES-2 shows the most important management actions for ocean- and stream-type salmonids that emerged from the analysis and planning exercises in the estuary recovery plan module. Many of these key actions are the same for ocean and stream types.

Implementing the suite of key actions in Table ES-2 for ocean-type salmonids would cost approximately $392 million and be expected to achieve approximately 88 percent of the survival target for ocean-type juveniles. (See Chapter 5 for a description of survival targets.) Implementing the suite of key actions for stream-type salmonids would cost approximately $408 million and be expected to achieve 90 percent of the survival target. Additionally, an estimated annual gain of about 1,000 adult salmon and steelhead is associated with the implementation of CRE-14, "Reduce predation by pinnipeds." The lists of priority actions in Table ES-2 for ocean- and stream-type salmonids contain eight actions that are predicted to benefit both types of salmonids. Implementing this common set of actions would cost approximately $372 million and would be expected to yield survival improvements of roughly 3 million juveniles.

TABLE ES-2
Management Actions Most Important for Survival of Ocean- and Stream-type Salmonids

| For Ocean Types | For Stream Types |
|---|---|
| CRE-01: Protect/restore riparian areas. | CRE-01: Protect/restore riparian areas. |
| CRE-04: Adjust the timing, magnitude, and frequency of hydrosystem flows. | CRE-04: Adjust the timing, magnitude, and frequency of hydrosystem flows |
| CRE-08: Remove or modify pilings and pile dikes. | CRE-08: Remove or modify pilings and pile dikes. |
| CRE-09: Protect/restore high-quality off-channel habitat. | CRE-09: Protect/restore high-quality off-channel habitat. |
| CRE-10: Breach, lower, or relocate dikes and levees. | CRE-10: Breach, lower, or relocate dikes and levees. |
| CRE-13: Manage pikeminnow and other piscivorous fish. | CRE-13: Manage pikeminnow and other piscivorous fish. |
| CRE-21: Identify and reduce sources of pollutants. | CRE-21: Identify and reduce sources of pollutants. |
| CRE-22: Restore or mitigate contaminated sites. | CRE-22: Restore or mitigate contaminated sites. |
| ***CRE-02: Mitigate/reduce reservoir-related temperature changes.*** | ***CRE-14: Reduce predation by pinnipeds.*** |
| | ***CRE-16: Redistribute Caspian terns.*** |
| | ***CRE-17: Redistribute cormorants.*** |

Note: Bold-face italics indicate management actions that would benefit primarily ocean- or stream-type salmonids, rather than both types.

## Other Implementation Considerations: Life History Diversity, Cost-Effectiveness, and Achieving Maximum Benefit

It is tempting to pick and choose among the management actions, looking for the path of least resistance to achieve the desired survival improvements. For example, using the results of the Chapter 7 survival improvement planning exercise, it appears obvious that significant improvements in the survival of stream-type salmonids can be achieved by reducing threats associated with predators such as terns, cormorants, pikeminnow, and pinnipeds. However,

addressing these threats would improve survival primarily for the dominant life-history strategy displayed by stream-type salmonids; in terms of recovery of ESUs, less dominant stream-type life history strategies also must be addressed. This points to the need to implement additional management actions in the estuary not directly related to predation.

For ocean-type juveniles, management actions that improve the health of the estuarine ecosystem appear to be the linchpin. Ocean-type juveniles reside in the estuary longer than stream types do. As a result, they rely more heavily on a healthy estuarine ecosystem to provide them with food and habitat (Bottom et al 2005). Given the challenges of making wide-scale ecosystem change, significant improvements for ocean-type juveniles may depend largely on three of the most constrained actions: adjusting hydrosystem flows (CRE–4), establishing or improving access to off-channel habitats (CRE-10), and restoring contaminated sites (CRE-22). Although these are some of the most expensive actions, their effects could be far-reaching enough that their potential benefits would be at least commensurate with their high costs.

Finally, because the estuary recovery module (by design) takes an optimistic view about what is possible in terms of reducing the constraints to implementation of management actions, in actuality specific actions probably will not be implemented with the level of effort needed to elicit the desired response. In fact, the most important take-home message of the estuary plan module is that recovery of listed ESUs in the Columbia River may not be possible without properly functioning estuary and plume ecosystems. To achieve a meaningful boost in survival from these ecosystems, every ounce of an action's potential benefit should be explored, and serious consideration should be given to implementing all of the 23 management actions to the fullest extent possible.

CHAPTER 1

# The Columbia River Estuary and Plume

## Purpose and Development of the Estuary Recovery Plan Module

This estuary recovery plan module is a planning document intended to complement other recovery plans in the region. With few exceptions, the module's focus is limited to habitat conditions and processes in the Columbia River estuary and plume, rather than hatchery or harvest practices, hydroelectricity production, or tributary habitats in the Columbia River basin. The purpose of this estuary recovery plan module is to identify and prioritize habitat-related management actions that, if implemented, would reduce threats to salmon and steelhead in the Columbia River estuary and plume.[1]

Chapter 2 provides background information on salmonid use of the estuary and plume within the context of the entire Columbia River basin. Chapter 3 identifies and prioritizes habitat-related salmon and steelhead limiting factors, and Chapter 4 links these limiting factors to the underlying environmental and human threats that have contributed to declines in abundance in the estuary. Chapter 4 also prioritizes threats based on the priority of the limiting factors they contribute to and their relative contribution to those limiting factors. Chapter 5 describes management actions that have the potential to reduce threats and evaluates the actions in terms of their implementation constraints, potential benefits, and costs. Chapter 6 describes research, monitoring, and evaluation needs, while Chapter 7 integrates elements of the earlier chapters to help characterize scenarios for improving the survival of salmonids as they rear in and migrate through the estuary and plume.

This estuary recovery plan module was developed by PC Trask & Associates, Inc., with participation of staff at the Lower Columbia River Estuary Partnership. The author also coordinated closely with staff at NOAA's National Marine Fisheries Service (NMFS) Northwest Regional Office throughout the module development process and obtained additional guidance and input from NMFS Northwest Fisheries Science Center staff and other regional experts (see Acknowledgements).

In drafting the module, the author reviewed and synthesized information from three main source documents:

- *Salmon at River's End: The Role of the Estuary in the Decline and Recovery of Columbia River Salmon* (Bottom et al. 2005)—Technical memorandum by the NMFS Northwest Fisheries Science Center

[1] Although current scientific information on the effects of limiting factors and actions does not differentiate between hatchery- and natural-origin salmon and steelhead, or between salmon and steelhead that are listed under the Endangered Species Act (ESA) and those that are not, the intent of the module is to improve the survival of ESA-listed salmon and steelhead. ESA recovery is determined by the status of naturally produced salmon and steelhead.

- *Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead: An Evaluation of the Effects of Selected Factors on Salmonid Population Viability* (Fresh et al. 2005)—Technical memorandum by the NMFS Northwest Fisheries Science Center
- "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan" and its supplement—Northwest Power and Conservation Council (2004)

NMFS Northwest Regional Office staff considered these documents to be timely, comprehensive, and accurate summaries of existing scientific knowledge about the estuary; they proved particularly valuable in providing information about threats and limiting factors affecting salmonids in the estuary.

To clarify key points or address topics that were not included in Bottom et al. (2005), Fresh et al. (2005), and Northwest Power and Conservation Council (2004), the author reviewed additional literature and contacted researchers whose findings were relevant but as yet unpublished; this included researchers at the NMFS Northwest Fisheries Science Center. Area experts (see Acknowledgements) reviewed and helped refine the author's draft products; thus, the module relies heavily on expert opinion rather than an expert panel or "Delphi" process. The author also worked with NMFS Northwest Regional Office and Lower Columbia River Estuary Partnership staff to further revise the module based on comments received during a *Federal Register* public review period. In summary, the final module is a broader, more comprehensive document than the three key source documents and has evolved with input from a diversity of scientists, other specialists, and the public.

Although the estuary recovery plan module is scientifically based, it is primarily a planning document and has important relationships to other planning processes and documents in the region. In the context of Columbia River basin recovery planning, the estuary module provides information on how conditions in the estuary and plume affect the 13 listed Columbia Basin evolutionarily significant units (ESUs). It was distributed in draft form to recovery planning forums around the Columbia River basin, and presentations on the module were made to Oregon's Mid-Columbia Sounding Board, the Upper Willamette Recovery Planning Stakeholder Team, and the Oregon Lower Columbia River Recovery Planning Stakeholder Team.

In the context of lower Columbia River management plans, the estuary recovery plan module is consistent with information in the Northwest Power and Conservation Council's "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan" (in *Columbia River Basin Fish and Wildlife Program*, Northwest Power and Conservation Council 2004), the Lower Columbia River Estuary Partnership's *Comprehensive Conservation and Management Plan*, and the Columbia River Estuary Study Taskforce's Columbia River Estuary Data Development Program. In addition, information in the module was used in the Federal Columbia River Power System (FCRPS) 2008 Biological Opinion (BiOp) and later incorporated into the 2010 Supplemental BiOp; information from the module also was used in Washington's Lower Columbia Fish Recovery Board planning process, Oregon's Lower Columbia River recovery planning process, and other recovery planning efforts throughout the Columbia River basin.

The process of identifying and prioritizing management actions in the estuary module has inherent difficulties. Although scientific knowledge about the estuary is advancing, it is still

incomplete. In addition, effective management solutions must acknowledge irreversible changes in estuary conditions over time, reflect the social and political will of the region, and focus on the biological and physical needs of the fish. In the final analysis, it is likely that science will never fully explain how every action affects the viability of fish. It will be up to current and future residents of the basin to determine how much they are willing to pay or do without in order to return salmon and steelhead to viable levels.

## Formation and Current Characteristics of the Estuary

The geographic scope of the estuary recovery module encompasses areas from Bonneville Dam (River Mile [RM] 146; River Kilometer [RKm] 235) to the mouth of the Columbia River, including the Columbia River plume. The scope includes the lower portion of the Willamette River (from Willamette Falls, at RM 26.6 [RKm 42.6], to the Willamette's confluence with the Columbia River), along with the tidally influenced portions of other tributaries below Bonneville Dam. (Tidal portions of tributaries entering the estuary also are addressed in the Lower Columbia Fish Recovery Board's *Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan* [2010] and Oregon's *Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead* [ODFW 2010] in a manner consistent with the overall framework of this module.)

The Columbia River estuary is a former river valley that, during the last ice age, was carved to 110 meters (360 feet) below current sea level. As sea levels subsequently rose, the floor of the valley was submerged and began to fill with sediments—initially from eastern drainages and then from the Cascade Range. The Missoula Floods, which occurred roughly 15,000 to 13,000 years ago, filled the valley with sand. This was followed by rapid sea level rise, which increased the size of the estuary and allowed further accumulation of mud and sand. By about 9,500 years ago, the rate of sea level rise had declined, the former river valley had filled with sediments, and most suspended sediment and bed load sand arriving from the Columbia River were being transported through the estuary to marine areas via the action of ebb tides and spring freshets, with some suspended sediment being deposited in floodplains and peripheral bays. This pattern continued to the historical period (Petersen et al. 2003).

The historical (circa 1880) total surface area of the Columbia River estuary has been estimated at up to 186 square miles (482 square kilometers) (Thomas 1983, Simenstad et al. 1984 as cited in Northwest Power and Conservation Council 2004). The current estuary surface area is approximately 159 square miles (412 square kilometers) (Northwest Power and Conservation Council 2004). The Willamette River is the largest tributary to the lower Columbia River. Other major tributaries originating in the Cascade Mountains include the Sandy River in Oregon and the Washougal, Lewis, Kalama, and Cowlitz rivers in Washington. Coastal range tributaries include the Elochoman and Grays rivers in Washington and the Lewis and Clark, Youngs, and Clatskanie rivers in Oregon. The general geography of the estuary is shown in Figure 1-1.

**FIGURE 1-1**
The Columbia River Estuary and Its Major Tributaries
(Reprinted from Bottom et al. 2005.)

Tidal impacts in water levels are observed as far upstream as Bonneville Dam at RM 146 (RKm 235). During low flows, reversal of river flow has been measured as far upstream as Oak Point at RM 53 (RKm 84.8). The intrusion of saltwater is generally limited to Harrington Point at RM 23 (RKm 36.8); however, at lower daily flows saltwater intrusion can extend past Pillar Rock at RM 28 (RKm 44.8).

Today, the lowest river flows occur during September and October, when rainfall and snowmelt are lowest (Northwest Power and Conservation Council 2004). The highest flows occur from April to June and result from snowmelt runoff. High flows also occur between November and March and are caused by heavy winter precipitation. Discharge at the mouth of the river typically ranges from 100,000 to 500,000 cubic feet per second (cfs). Historically, unregulated flows were both lower and higher—79,000 and 1 million cfs, respectively (Neal 1972 and Lower Columbia River Estuary Partnership 2002 as cited in Northwest Power and Conservation Council 2004).

# Estuary Reaches

For the purposes of this estuary recovery plan module, the estuary is broadly defined to include the entire continuum where tidal forces and river flows interact, regardless of the

extent of saltwater intrusion (Fresh et al. 2005, Northwest Power and Conservation Council 2004). For planning purposes, the upstream boundary is Bonneville Dam and the downstream boundary includes the Columbia River plume. These two divisions—the estuary and plume—have been used extensively in this estuary recovery plan module as distinct zones. Further delineation of the estuary has occurred, including efforts by Thomas (1983), Johnson et al. (2003), and the Lower Columbia River Estuary Partnership (2005).

In this estuary recovery plan module, limiting factors, threats, and management actions are identified at the finest reach level possible. In some cases, this may be as general as making a distinction between the estuary and plume. In other cases, additional definition is available at the reach scale. The Lower Columbia River Estuary Partnership, in conjunction with the University of Washington and U.S. Geological Survey, has developed and is continuing to refine several estuary landscape classifications. Of these overlaying classifications, the estuary recovery module uses the Level 3 Stratum, which organizes the estuary between the mouth and Bonneville Dam into eight lettered reaches (Lower Columbia River Estuary Partnership 2005).

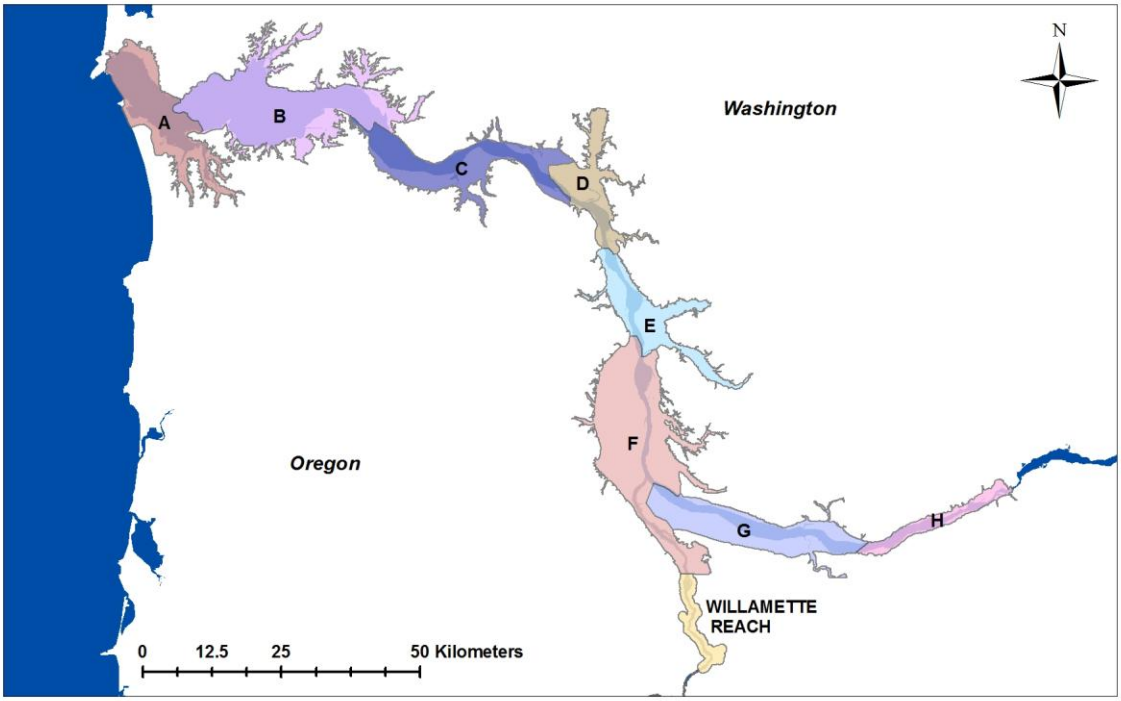


**FIGURE 1-2**
Lower Columbia River Estuary Reaches
(Adapted from Northwest Power and Conservation Council 2004.)

Figure 1-2 shows these eight reaches, which can be described briefly as follows:

- **Reach A**. This area includes the estuary entrance (Clatsop Spit and Trestle Bay), Bakers Bay, and Youngs Bay. The entrance is dominated by subtidal habitat and has the highest salinity in the estuary. Historically, the estuary entrance was a high-energy area of natural fluvial land forms with a complex of channels, shallow water, and sand bars.

Reach A supports the Columbia River plume, which creates a unique low-salinity, high-productivity environment that extends well into the ocean. The dynamic nature of the entrance area has changed as a result of dredging and the construction of jetties. These activities have limited wave action and the marine supply of sediment.

Historically, ocean currents and wave action made Bakers Bay a high-energy area, but both currents and wave action have been altered by dredging and jetty construction. The migration of mid-channel islands toward the interior of Baker Bay also has sheltered the area from wave action. As a result, tidal marsh habitat has recently started to develop in some areas, although much of the historical tidal marsh and tidal swamp habitat has been lost because of dike construction in the floodplain. Given its proximity to the river mouth, Baker Bay consists primarily of brackish water.

Youngs Bay is characterized by a broad floodplain and historically was abundant in tidal marsh and swamp habitat. Diking and flood control structures have been used to convert floodplain habitat in the area to pasture. The remaining fragmented tidal marsh and tidal swamp habitats in Youngs Bay are thought to be different in structure and vegetative community than historical conditions of these habitats.

- **Reach B**. Reach B generally extends from the Astoria-Meglar Bridge upstream to the westernmost tip of Puget Island. This area includes what has been referred to as the mixing zone (Northwest Power and Conservation Council 2004), along with Grays Bay and Cathlamet Bay. The mixing zone is an area characterized by a network of mid-channel shoals and flats, such as Desdemona and Taylor Sands. It also has the highest variation in salinity within the estuary because of the interactions between tide cycles and river flows. The estuarine turbidity maximum (see p. 3-8), which is created through these interactions, is often located within this area of Reach B. Many islands are found in Reach B, including Tenasillahe, Horseshoe, Marsh, Karlson, Russian, Svensen, Miller Sands, Rice, and Lois islands.

  Grays Bay is found on the Washington side of the river in Reach B. Historically, water circulation in this area was a result of interactions between river flow and tidal intrusion. Pile dike fields constructed adjacent to the main Columbia River navigation channel have decreased circulation in Grays Bay. This circulation change is suspected of causing flooding problems in the Grays and Deep River valley bottoms and may have promoted the beneficial development of tidal marsh habitat in the accreting bay. Dike construction, primarily for pasture conversion, has isolated the main channel from its historical floodplain and eliminated much of the historical tidal swamp habitat.

  Cathlamet Bay is located on the Oregon side of the river in Reach B. This area is characterized by some of the most intact and productive tidal marsh and swamp habitat remaining in the estuary, and a large portion of Cathlamet Bay is protected by the Lewis and Clark National Wildlife Refuge. The western edge of Cathlamet Bay contains part of the brackish oligohaline zone, which is thought to be important during the transition of juvenile anadromous fish from freshwater to saltwater. Portions of Cathlamet Bay have lost substantial acreage of tidal swamp habitat as a result of dike construction. Conversely, tidal marsh habitat has formed along the fringe of dredge disposal locations.

- **Reach C**. This area, which includes deep channels and steep shorelines on the Washington side of the river, extends from the westernmost tip of Puget Island to the western edge of Longview. Historically, Reach C contained significant acres of tidal swamp dominated by sitka spruce. Dike construction and clearing of vegetation have resulted in a substantial loss of tidal marsh habitat on islands and floodplain in the Oregon portion of Reach C. Lord Walker, Hump Fisher, Crims, Wallace and Puget islands are located within Reach C.
- **Reach D**. This area begins west of Longview and ends north of the city of Kalama. Reach D is distinct from the downstream reaches in its geology, vegetation, and climate. It includes flows from the Cowlitz and Kalama rivers. Extensive diking and filling around Longview and the mouth of the Kalama River have significantly reduced access to the floodplain. Islands and shoreline have been extensively modified through the disposal of dredged material. Sediment loading from eruptions of Mount St. Helens have significantly altered hydrology and channel morphology in and downstream of the Cowlitz and Kalama rivers. Dredging and the disposal of sediment from Mount St. Helens have been extensive. The two primary islands in Reach D are Cottonwood and Howard. High levels of polychlorinated biphenyls (PCBs) have been detected in the Longview and Kalama industrial area.
- **Reach E**. This area includes the Columbia River south of the city of Kalama to the confluence with the Lewis River, adjacent to the city of St. Helens, Oregon. The Lewis River system, including the North Fork and East Fork, flows into the Columbia River in Reach E. Sandy, Goat, Deer, Martin, and Burke islands are included in Reach E. Several of these islands, including Sandy and Goat islands, were created through the placement of dredged materials). Extensive diking has occurred on Deer Island and around the city of Woodland, Washington.
- **Reach F**. This area includes the Columbia River south of the confluence with the Lewis River up to and including the mid-point of Hayden Island. Reach F also extends into the Willamette River, to the downstream tip of Ross Island. Reach F is generally rural in character; however, it is located immediately downstream of the most urban/industrial areas in the entire Columbia River. Reach F contains the largest historical floodplain lakes below Bonneville Dam: Sturgeon Lake, at about 3,600 acres, and Vancouver Lake, which is approximately 2,400 acres. The historical floodplain was very wide in Reach F relative to the narrow and constricted channel through the Columbia River Gorge. Islands included in this reach are Bachelor and Sauvie islands. Sloughs include the 13-mile Lake River system and the more than 20-mile-long Multnomah Channel. Scappoose Bay is relatively undiked; however, Sauvie Island and Bachelor Island have been extensively diked. Reach F also includes Portland Harbor, a heavily industrialized stretch of the Willamette River located north of downtown Portland that was listed as a Superfund site in December 2000. Sediments in the river at this site are contaminated with various toxic compounds, including metals, polycyclic aromatic hydrocarbons (PAHs), PCBs, chlorinated pesticides, and dioxin (Oregon Department of Environmental Quality 2008).
- **Reach G**. This area includes the Columbia River west of Hayden Island and extends to just east of Reed Island. Major tributaries include the Washougal and Sandy rivers. The cities of Portland and Vancouver straddle the Columbia River in this reach. Islands included in this reach are Hayden Island, Government Island, Lady Island, and Reed

Island. Extensive diking has reduced the floodplain throughout the reach. Smith and Bybee lakes represent a large floodplain lake system similar to that of Vancouver and Sturgeon lakes in Reach F. Significant numbers of industrial piers and over-water structures line the Columbia rivers in this reach.

- **Reach H**. This area includes the Columbia River from east of Reed Island to the Bonneville Dam. This reach receives flow from many small tributaries, including Gibbons, Duncan, Hamilton, Hardy, and Multnomah creeks. Notable islands in this reach include Ackerman and Skamania islands. Reach H includes the entrance to the Columbia River Gorge, which is characterized by steep slopes. Little diking has occurred in this area, primarily because the steep adjacent slopes on both side of the river have naturally constrained the floodplain.
- **Lower Willamette Reach**. This reach extends upstream from the northern tip of Ross Island to Willamette Falls at RM 26.6 (RKm 42.6). The Lower Willamette reach is highly urbanized, bisecting the city of Portland and flowing past the cities of Milwaukie, Lake Oswego, Gladstone, and Oregon City. Notable islands in the Lower Willamette reach include Ross and Hardtack, Elk Rock, Hog, Cedar, and Goat islands. The primary tributary entering the Lower Willamette reach is the Clackamas River just downstream of Willamette Falls. Other smaller tributaries include Johnson, Tryon, Kellogg, Miller, and Stephens creeks. The shoreline of the Lower Willamette reach has been highly modified for industry, flood control, and other uses. Twelve transportation bridges cross the Willamette River in this reach.

GIS maps of each of the reaches are presented in Appendix A. The maps show additional information such as the locations of pile dikes and some tide gates, the navigation channel, the historical floodplain, diked areas, and dredged material placement sites.

## Columbia River Plume

The Columbia River plume is generally defined by a reduced-salinity contour near the ocean surface of approximately 31 parts per thousand (Fresh et al. 2005). In high flows, the plume front is easily recognized by the sharp contrast between the sediment-laden river water and the clearer ocean (see Figure 1-3). The plume's location varies seasonally with discharge, prevailing near-shore winds, and ocean currents. In summer, the plume extends far to the south and offshore along the Oregon coast. During the winter, it shifts northward and inshore along the Washington coast. Strong density gradients between ocean and plume waters create stable habitat features where organic matter and organisms are concentrated (Fresh et al. 2005). The Columbia River plume can extend beyond Cape Mendocino, California, and influences salinity in marine waters as far away as San Francisco (Northwest Power and Conservation Council 2000). For the purposes of this estuary recovery plan module, the plume is considered to be off the immediate coasts of both Oregon and Washington and to extend outward to the continental shelf.

## Major Land Uses

A variety of land uses are found adjacent to the Columbia River estuary. The area contains multiple cities and political jurisdictions, including Portland, which is Oregon's largest city, and Vancouver, the fourth largest Washington city. Smaller cities include Astoria,

Cathlamet, Longview, Kalama, Woodland, and Camas. Approximately 2.5 million people live in the vicinity of the estuary, and more are coming. Five deep-water ports in the area support a shipping industry that transports 30 million tons of goods annually (Lower Columbia Fish Recovery Board 2004), worth $13 billion each year (Columbia River Channel Improvement Reconsultation Project). Timber harvest occurs throughout the basin—six major pulp mills contribute to the region's economy. Until the early 2000s, aluminum plants along the river produced more than 40 percent of the country's aluminum. Agriculture is widespread throughout the floodplain and includes fruit and vegetable crops along with beef and dairy cattle. Commercial and recreational fishing activity plays an important role in local economies, bringing in millions of dollars of revenue each year. Primary outdoor recreational activities include fishing, wildlife observation, hunting, boating, hiking, and windsurfing.

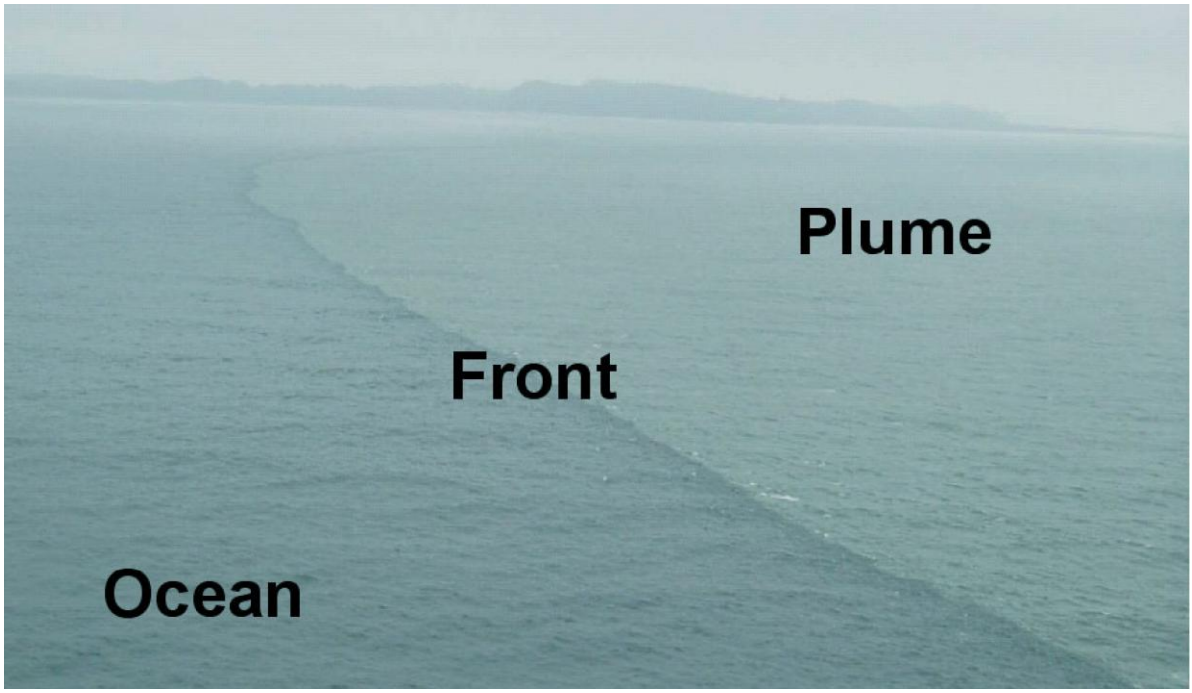


**FIGURE 1-3**
Plume Front
(Photo courtesy of NMFS.)

## Two Centuries of Change

Before Euro-American settlement of the Pacific Northwest, the Columbia River estuary and plume served as a physical and biological engine for salmon. Juveniles from hundreds of populations of steelhead, chum, Chinook, and coho entered the estuary and plume every month of the year, with their timing honed over evolutionary history to make use of habitats rich with food. A beach seine survey during any month of the year would likely have yielded salmon of all species and many populations, with individuals of many sizes. This genetic variation in behavior was an important trait that allowed salmon and steelhead

to occupy many habitat niches in time and space. It also guarded populations against catastrophic events such as volcanic eruptions (Bottom et al. 2005).

Today the Columbia River estuary and plume are much different. Notably, the North and South jetties at the mouth of the river restrict the marine flow of nutrients into the estuary. Dikes and levees lining the Washington and Oregon shores prevent access to areas that once were wetlands. New islands have been formed by dredged materials, and pile dike fields reach across the river, redirecting flows. Less visible but arguably equally important are changes in the size, timing, and magnitude of flows that, 200 years ago, regularly allowed the river to top its banks and provide salmon and steelhead with important access to habitats and food sources. Flow factors, along with ocean tides, are key determinants of habitat opportunity and capacity in the estuary and plume.

Salmon have thrived in the Columbia River for up to 1 million years (Lichatowich 1999). In the last 100 years, the entire Columbia River has undergone tremendous change as a direct result of people living and working in the basin. While the threats to salmon persistence are very diverse, at some level it is the increase in human population in the Northwest that underlies every human threat. There are an estimated 5 million people in the Columbia River basin today, and somewhere between 40 million and 100 million people are predicted to be living in the basin by the end of the twenty-first century (National Research Council 2004). If we want healthy salmon runs at the same time that our population is multiplying, our interactions with land and water must pose fewer threats to salmonids than they have in the last 100 years. Before identifying management actions that could do just that, this document discusses which salmonids currently use the Columbia River basin, and how.

CHAPTER 2

# Salmonid Use of the Estuary and Plume

The estuary and plume provide salmonids with a food-rich environment where they can undergo the physiological changes needed to make the transition from freshwater to saltwater habitats, and vice versa. Every anadromous salmonid that spawns in the Columbia River basin undergoes such a transformation twice in its lifetime—the first time during its first year of life (or soon after) when migrating out to sea, and the second time 1 to 3 years later, as an adult returning to spawn. The transition zone where juvenile salmonids undergo this transformation is thought to extend from the estuary itself to the near-shore ocean and plume habitats and into rich upwelling areas near the continental shelf (Casillas 1999).

The estuary and plume also serve as rich feeding grounds where juveniles have the opportunity for significant growth as they make the important transition from freshwater to seawater. Studies have shown that juvenile salmon released within the estuary and plume returned as larger adults and in greater numbers than juveniles released outside the transition zone (Emmett and Schiewe 1997 as cited in Casillas 1999). Thus, although juvenile salmonids face risks from a variety of threats in the estuary and plume (see Chapter 4), these environments can be highly beneficial. In the salmon life cycle, successful estuarine and plume residency by juveniles is critical for fast growth and the transition to a saltwater environment.

Clearly, the Columbia River estuary and plume are uniquely important to salmonids, and conditions in the estuary and plume undoubtedly affect salmonid survival. Yet the estuary and plume represent just one in a series of ecosystems that salmon use in their complex life cycle. Exploring the connections among these ecosystems, the habitats they provide, the salmonid species that use them, and the variety of life histories those salmonids display sheds further light on the role of the estuary and plume in the salmonid life cycle.

## Salmonid Species in the Columbia River Basin

Before Euro-American settlement, the Columbia River basin was used extensively by six species of the family Salmonidae and the genus *Oncorhynchus*: Chinook, chum, coho, and sockeye salmon plus two trout species: steelhead and sea-run cutthroat (Lichatowich 1999). Within these six species, 13 ESUs,[1] representing more than 150 populations of salmon and steelhead, have been listed as threatened or endangered under the Federal Endangered Species Act (Bottom et al. 2005). All 13 of the ESUs use the estuary and plume as an essential link in their far-reaching life cycles.

[1] NMFS has revised its species determinations for West Coast steelhead under the Endangered Species Act (ESA), delineating steelhead-only "distinct population segments" (DPSs). The former steelhead ESUs included both anadromous steelhead trout and resident, non-anadromous rainbow trout, but NMFS listed only the anadromous steelhead. The steelhead DPS does not include rainbow trout, which are under the jurisdiction of the U.S. Fish and Wildlife Service. In January 2006, NMFS listed five Columbia River basin steelhead DPSs as threatened (71 FR 834). To avoid confusion, references to ESUs in this estuary recovery plan module imply the steelhead DPSs as well.

It is estimated that historically up to 16 million salmon from perhaps hundreds of distinct populations returned to the Columbia River each year (Lichatowich 1999). This contrasts markedly with recent returns of salmon and steelhead adults, which have averaged about 1.7 million, with 65 to 75 percent of those fish being of hatchery origin.[2] For 2006, scientists from the NMFS Northwest Fisheries Science Center estimated that about 168 million juveniles would enter the estuary (Ferguson 2006b).[3] This suggests that only 1 percent of the juveniles entering the estuary will return as adults and 99 percent are lost as a result of all the limiting factors (human and natural) in the estuary, plume, nearshore, and ocean.

# Life History Types and Strategies

In discussing salmonids, fish scientists commonly refer to ocean type and stream type to distinguish two main freshwater rearing strategies. Ocean-type salmonids are characterized by migration to sea early in their first year of life, after spending only a short period in freshwater (Fresh et al. 2005). Ocean types may rear in the estuary for weeks or months, making extensive use of shallow, vegetated habitats such as marshes and swamps, where significant changes in flow and habitat have occurred (Fresh et al. 2005). Conversely, stream-type salmonids are characterized by migration to sea after rearing for more extended periods in freshwater, usually at least 1 year (Fresh et al. 2005). Table 2-1 shows the general characteristics of ocean-type and stream-type ESUs.

**TABLE 2-1**
Characteristics of Ocean- and Stream-Type Salmonids

| Attribute | Ocean-Type Fish: fall Chinook, chum | Stream-Type Fish: coho, spring Chinook, steelhead |
|---|---|---|
| Residency time | Short freshwater residence<br>Longer estuarine residence<br>Longer ocean residence | Long freshwater residence (>1 year)<br>Shorter estuarine residence<br>Shorter ocean residence |
| Size at estuary entry | Smaller | Larger |
| Primary habitat use | Shallow-water estuarine habitats, especially vegetated ones | Deeper, main-channel estuarine habitats; use plume more extensively |

Adapted from Fresh et al. 2005.

In the Columbia River estuary, both ocean- and stream-type salmonids experience significant mortality. However, because the two types typically spend different amounts of time in the estuary and plume environments and use different habitats, they are subject to somewhat different combinations of threats and opportunities.

For ocean-type juveniles, mortality is believed to be related most closely to lack of habitat, changes in food availability, and the presence of contaminants, including persistent, bioaccumulative contaminants present in sediments in the shallow-water habitats where ocean-type juveniles rear in the estuary. Stream types are affected by these same factors, although presumably to a lesser degree because of their shorter residency times in the

[2] This is an informal estimate; determining the ratio of hatchery-origin fish with more certainty would require stock-by-stock run calculations averaged over many years.

[3] 2006 was a normative year and is considered representative.

estuary. However, stream types are particularly vulnerable to bird predation in the estuary because they tend to use the deeper, less turbid channel areas located near habitat preferred by piscivorous birds (Fresh et al. 2005), and they are subject to pinniped predation when they return to the estuary as adults (see Chapter 3). Also, scientists at the NMFS Northwest Fisheries Science Center now hypothesize that larger numbers of stream-type yearling juveniles are susceptible to predation by northern pikeminnow than was previously thought; this predation occurs as the juveniles move into the shallows behind structures such as pilings or pile dikes to forage (Casillas 2007); this and related hypotheses are in the process of being tested through a program initiated by the Federal action agencies (the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, and Bonneville Power Administration) and the Lower Columbia River Estuary Partnership. Additionally, stream-type salmonids are thought to use the low-salinity gradients of the plume to achieve growth and gradually acclimate to saltwater. Changes in flow and sediment delivery in the plume may affect stream-type juveniles in a way similar to how estuary conditions affect ocean-type juveniles; however, additional research is needed to determine more precisely how stream types use the plume (Casillas 2006).

Fish scientists also describe salmonids in terms of the life history strategies they employ, meaning a population's unique pattern of preferred spawning substrate, habitat use, migration timing, length of estuarine and marine residency, and so on. For thousands of years, Columbia River salmonids exhibited great diversity in life history strategies, exploiting a wide array of the habitat niches available to them. This rich diversity in life history strategies allowed salmonids to persist as species for millennia even when individual populations were wiped out by disease or natural disturbances such as volcanic eruptions.

Table 2-2 identifies the six basic life history strategies used by salmon and steelhead in the Columbia River and their general attributes.

## Changes in Life History Diversity

The 13 listed ESUs in the Columbia River express much less diversity in life history strategies now than they did historically. Formerly, both ocean- and stream-type salmonids entered the estuary and plume throughout the year, at a great variety of sizes, which reflected the various life history strategies in Table 2-2. Today juveniles tend to arrive in pulses and are more uniform in size.

Table 2-3 shows losses in life history diversity in the Columbia River. The table identifies the dominant life history type (ocean vs. stream) and strategies for each ESU, the prevalence of each life history strategy, and whether that prevalence has changed from historical times to the present. The number of life history strategies employed by some ESUs, such as Columbia River chum, have not changed. But for other ESUs—notably the Lower Columbia River coho—several life history strategies that used to exist have been lost. In a research project studying outmigration of juvenile Chinook salmon in the lower Willamette River, results indicated the presence of fry and fingerling juveniles in all months of the year. Although the specific ESUs of these juvenile salmon have not been confirmed, the results indicate more contemporary life history stages present than indicated in Table 2-3 (Friesen et al. 2007).

Losses in life history diversity can also be seen in Figure 2-1, which compares historical and current estuarine life history types for one brood year of Chinook salmon. The figure shows a reduction in the number of strategies available in the contemporary versus historical estimates.

Some of the losses in salmonid life history diversity are attributable to habitat alterations throughout the Columbia River basin that have eliminated entire populations of salmon and steelhead. In other cases, hatcheries and harvest impacts have reduced the health and genetic makeup of species. As a result, many of the populations currently using the estuary and plume are significantly different than the fish that historically used the various habitats available to them, and some existing habitats may not be being used by salmonids at all.

**TABLE 2-2**
Life History Strategies and Their Attributes

| Life History Strategy | Attributes |
|---|---|
| Early fry | Freshwater rearing: 0 - 60 days<br>Size at estuarine entry: <50 mm<br>Time of estuarine entry: March - April<br>Estuarine residence time: 0 - 40 days |
| Late fry | Freshwater rearing: 20 - 60 days<br>Size at estuarine entry: <60 mm<br>Time of estuarine entry: May - June, present through Sept.<br>Estuarine residence time: <50 days |
| Early fingerling | Freshwater rearing: 60 - 120 days<br>Size at estuarine entry: 60 - 100 mm<br>Time of estuarine entry: April - May<br>Estuarine residence time: <50 days |
| Late fingerling | Freshwater rearing: 50 - 180 days<br>Size at estuarine entry: 60 - 130 mm<br>Time of estuarine entry: June - October, present through winter<br>Estuarine residence time: 0 - 80 days |
| Subyearling (smolt) | Freshwater rearing: 20 - 180 days<br>Size at estuarine entry: 70 - 130 mm<br>Time of estuarine entry: April - October<br>Estuarine residence time: <20 days |
| Yearling | Freshwater rearing: >1 year<br>Size at estuarine entry: >100 mm<br>Time of estuarine entry: February - May<br>Estuarine residence time: <20 days |

Adapted from Fresh et al. 2005.

**TABLE 2-3**
Linkage between Salmonid ESU, Dominant Life History Type, and Life History Strategy in the Columbia River Estuary

| ESU | Life History Type | Historical and Current Life History Strategies | | | | | |
|---|---|---|---|---|---|---|---|
| | | Early Fry | Late Fry | Early Fingerling | Late Fingerling | Sub-yearling | Yearling |
| Columbia River chum salmon | Ocean | Abundant | Abundant | — | — | — | — |
| Snake River sockeye salmon | Stream | — | — | — | — | Rare | Abundant |
| Lower Columbia River coho salmon | Stream | Historically rare, currently absent | Historically rare, currently absent | Historically rare, currently absent | Historically rare, currently absent | Rare | Abundant |
| Upper Columbia River steelhead | Stream | — | — | — | — | Historically rare, currently absent | Abundant |
| Snake River steelhead | Stream | — | — | — | — | Historically rare, currently absent | Abundant |
| Lower Columbia River steelhead | Stream | — | — | — | Historically rare, currently absent | Historically medium, currently rare | Abundant |
| Middle Columbia River steelhead | Stream | — | — | Historically rare, currently absent | Historically rare, currently absent | Historically medium, currently rare | Abundant |
| Upper Willamette River steelhead | Stream | — | — | — | — | Historically rare, currently absent | Abundant |
| Snake River fall Chinook salmon | Ocean | — | — | Historically medium, currently rare | Historically medium, currently rare | Abundant | Historically rare, currently medium |
| Upper Willamette River Chinook salmon | Ocean | Historically rare, currently absent | Historically rare, currently absent | Historically medium, currently rare | Historically medium, currently rare | Historically rare, currently medium | Abundant |
| Lower Columbia River Chinook salmon | Ocean | Historically medium, currently rare | Historically medium, currently rare | Historically medium, currently rare | Historically medium, currently rare | Historically medium, currently abundant | Rare |
| Upper Columbia River spring Chinook salmon | Stream | — | — | Historically rare, currently absent | Historically rare, currently absent | Rare | Abundant |
| Snake River spring/summer Chinook salmon | Stream | — | — | Historically rare, currently absent | Historically rare, currently absent | Rare | Abundant |

"—" = historically and currently absent.
Adapted from Fresh et al. 2005.

# Relationship of the Estuary to the Columbia River Basin

In 2005, scientists working at the NMFS Northwest Fisheries Science Center published a technical memorandum that establishes an ecologically based conceptual framework for understanding the estuary within the larger context of the Columbia River basin. In *Salmon*

*at River's End: The Role of the Estuary in the Decline and Recovery of Columbia River Salmon*, Bottom et al. (2005) hypothesize that Columbia River salmon's resilience to natural environmental variability is embodied in population and life history diversity, which maximizes the ability of populations to exploit available estuarine rearing habitats. Bottom et al.'s conceptual framework is based on Sinclair's (1988) member/vagrant theory, which proposes general principles for understanding marine species with complex life cycles. The member/vagrant theory serves as a useful tool for evaluating salmon's specific needs in estuaries in relation to the entire continuum of their habitat needs throughout their complex life cycles (Bottom et al. 2005).

Bottom et al. (2005) hypothesize that how an individual salmon or steelhead uses the ecosystems it encounters—when juveniles migrate, how big they are, what habitats they use, and how long they stay in a particular habitat—correlates directly to the discrete population of fish that individual is part of. In other words, different populations within ESUs employ different life history strategies. For example, two populations of steelhead within an ESU may produce juveniles of different sizes that enter the estuary at different times, and these juveniles may use distinct habitats that may be available only at that particular time.

Considering that the estuary is just one of three major ecosystems used by salmon and steelhead, the member/vagrant theory implies that how juveniles migrate and use estuarine habitat may depend as much on the status of upriver habitats and corresponding populations as on environmental conditions in the estuary itself (Bottom et al. 2005). In other words, if there is a close relationship between particular geographical features in the estuary and the life history of a discrete salmonid population, use of the estuary may reflect the abundance and life history strategy of the associated population, which is in part a function of upstream conditions. Thus, if salmonid migration and rearing behaviors in the estuary are linked to specific geographic features and those features are reduced or eliminated, mortality in the population that uses those features increases (Bottom et al. 2005). By the same token, if salmonid populations are lost because of other factors (such as blockage by dams), habitats in the estuary may be left unoccupied.

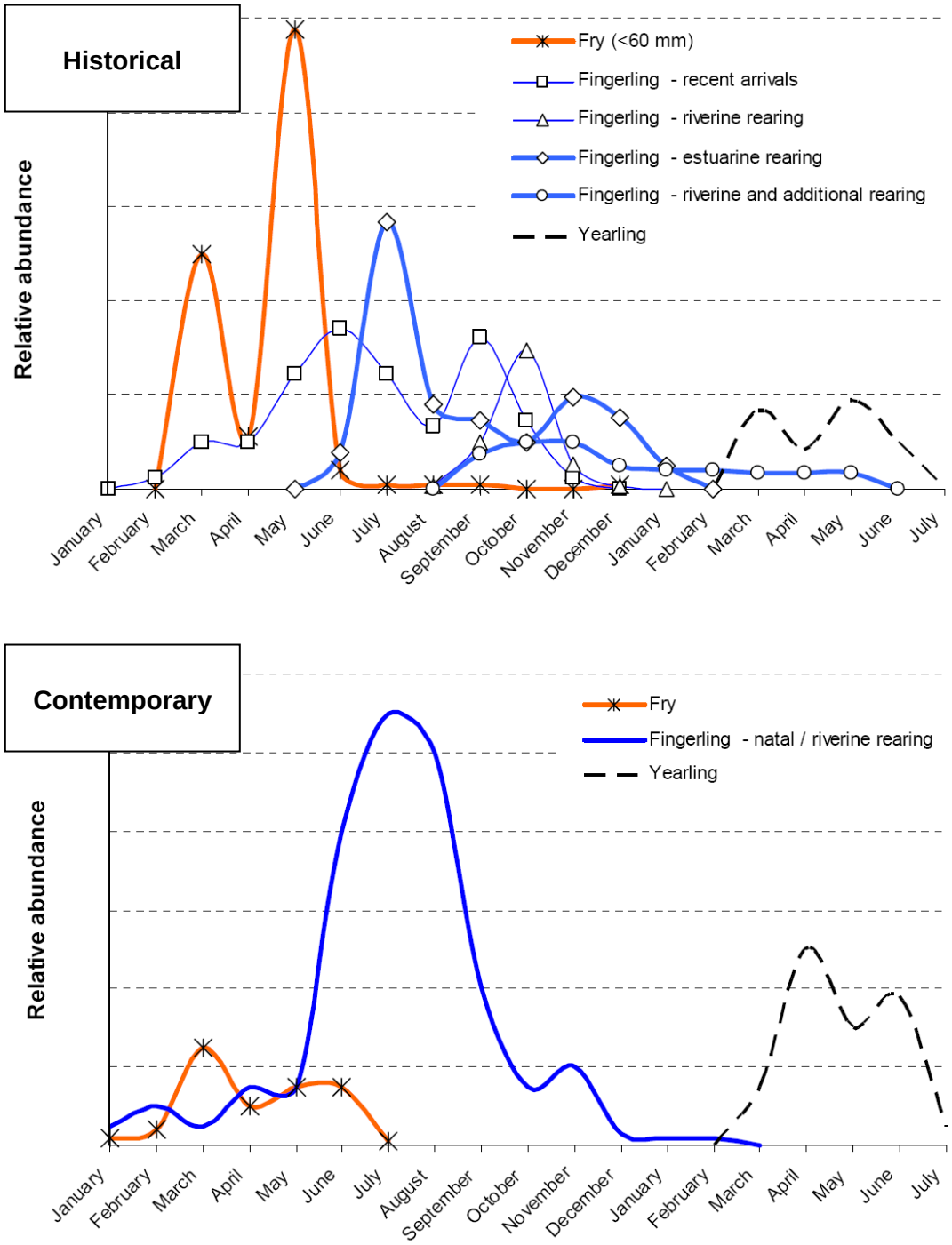


**FIGURE 2-1**
Historical and Contemporary Early Life History Types of Chinook Salmon in the Columbia River Estuary
(Reprinted from Fresh et al. 2005.)

The implication for salmon recovery in the Columbia River basin is that habitat use by salmonids must be considered from a multi-ecosystem perspective if we are to understand which components of each ecosystem—tributaries, mainstem, estuary, plume, nearshore, and ocean—are limiting the overall performance of salmon.

# Summary

Since 1991, 13 Columbia River ESUs have been listed as threatened or endangered under the Federal Endangered Species Act. During their complex life cycles, salmon and steelhead rely on many diverse ecosystems, from tributaries to ocean environments, that span hundreds or thousands of miles. For recovery efforts to be successful, it is necessary to understand salmonids' requirements during all stages of their life cycles. Thus, although the estuary and plume represent important stages in the salmonid life cycle, these ecosystems must be considered within the context of other life cycle stages if management actions are to be effective. Perhaps most central to the recovery of listed ESUs is the importance of conserving biological diversity and the native ecosystems it depends on (Bottom et al. 2005).

CHAPTER 3

# Limiting Factors

Chapter 3 identifies and prioritizes the key habitat-related physical, chemical, or biological features that scientific literature and area experts suggest are affecting the viability of ESUs and their component populations in the estuary. These features are referred to as limiting factors.[1] The discussion of limiting factors in this chapter pertains to the estuary and plume; however, upstream limiting factors in some cases have a direct bearing on conditions in the estuary. Discussion of limiting factors in this chapter generally relates to specific factors that limit salmonid productivity; however, it is recognized that the effects of multiple limiting factors may have a compounding effect. The estuary module does not address this compounding effect because of a lack of technical information to address the topic.

## Determining Estuary Habitat Limiting Factors

### Sources

It would be desirable to know with certainty which factors are responsible for the highest losses of salmon and steelhead in the estuary so that recovery actions could be focused on activities to address those factors. But as described below, researchers have quantified salmonid mortality in the estuary for only a few limiting factors, and additional research on mortality is needed to understand which factor (or factors) is most limiting salmonid viability in the estuary. In the absence of more comprehensive mortality data, the estuary recovery module relies on expert opinion and available information in the literature to identify and prioritize limiting factors.

PC Trask & Associates, Inc., based this chapter on a thorough review and synthesis of pertinent literature, supplemented by input from staff at the NMFS Northwest Fisheries Science Center and Northwest Regional Office, the Lower Columbia River Estuary Partnership, and the Lower Columbia Fish Recovery Board. The following documents, among others, provided consistent guidance:

- *Salmon at River's End: The Role of the Estuary in the Decline and Recovery of Columbia River Salmon* (Bottom et al. 2005)—Technical memorandum by the NMFS Northwest Fisheries Science Center
- *Role of the Estuary in the Recovery of Columbia River Basin Salmon and Steelhead: An Evaluation of the Effects of Selected Factors on Salmonid Population Viability* (Fresh et al. 2005)—Technical memorandum by the NMFS Northwest Fisheries Science Center
- "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan" and its supplement—Northwest Power and Conservation Council (2004)

These three literature sources, and others, identified and evaluated limiting factors in a similar manner. But it should be noted that the three sources have separate goals, and this

[1] In this module, the term "limiting factors" is used to indicate the full range of factors that are believed to be affecting the viability of salmon and steelhead in the estuary and not to indicate the single factor that is most limiting.

affects each document's structure and content. Thus, the depth and breadth of information were not always consistent across documents. To develop a relatively comprehensive list of factors that are limiting ESUs' viability in the estuary and to weigh the probable effect of each factor, the author had to synthesize information from multiple sources.

## Mortality Estimates

Estimates of salmon and steelhead mortality in the estuary and mainstem are not well supported in the literature, especially in the case of indirect mortality. (There are more reliable estimates of direct impacts to salmonids populations than indirect or combined impacts.) However, some modeling efforts have made assumptions about estuary mortality. One example is Ecosystem Diagnosis and Treatment (EDT), a life-cycle model that accounts for the estuarine stage of salmon and steelhead in tributaries of the Columbia River. For lower Columbia River ESUs, EDT assumes 18 to 58 percent mortality for various populations.

In addition, research is under way by NMFS, the U.S. Army Corps of Engineers, and Battelle Laboratories to estimate the survival rate of juvenile salmonids in the lower Columbia River. This research involves technologies for miniaturizing acoustic tags to a size capable of tracking yearling and subyearling juveniles. Current technology developed for the project allows for the tracking of subyearlings of sizes down to approximately 90 mm. Data from 2005 indicated an approximate range of survival of 65 to 75 percent for subyearlings and yearlings during their residency in the estuary (Ferguson 2006a).[2] It is probable that actual survival rates are lower than these estimates suggest because the research did not address mortality among juveniles smaller than 90 mm, mortality occurring in the plume and nearshore, or delayed mortality.

There are reliable mortality estimates for a few limiting factors. For example, Caspian tern predation was estimated to be responsible for the mortality of about 5.5 million smolts in 2007 (Roby et al. 2008)—up to 14.1 percent of in-river migrant steelhead smolts and 7.7 percent of transported steelhead smolts (Roby et al. 2008). Double-crested cormorants appear to be consuming approximately 6 percent of steelhead, 6 percent of subyearling Chinook, 2 percent of yearling Chinook, and 1 percent of sockeye salmon entering the estuary (Fredricks 2010).

Other limiting factors, such as pinnipeds (primarily affecting adult survival), ship wake stranding, and toxic contaminants, have incomplete mortality estimates associated with them. Toxic contaminants, for instance, can have lethal and sublethal impacts to salmonids, resulting in direct and indirect mortality, both of which are difficult to quantify. In most cases it is very difficult to point to a specific limiting factor and then estimate mortality. This is because of the inherent complexity associated with connecting the physical, chemical, and biological features that limit the productivity of salmon and steelhead.

[2] The mean yearling survival estimate for the years 2005 to 2009 is 75.8 percent (standard deviation = 5.4 percent), while the mean subyearling survival estimate for the same period is 67.6 percent (standard deviation = 9.0 percent) (Casillas 2010). Because these more current survival estimates are very close to the estimates used when the module was initially drafted, and because local recovery planners in the Washington and Oregon Lower Columbia region incorporated the 2005 estimates into their salmon recovery plans, the module was not updated with the most current numbers. In future revisions of the module and the Lower Columbia tributary plans, needed updates will be made.

## Density-Dependent Mortality

In the Columbia River estuary, limiting factors such as off-channel habitat availability, competition with native and exotic fish for food and space, disease, and predation by piscivorous fish and native birds may in part be manifestations of density dependence. Density dependence refers to changes in the size of a population that are themselves a result of the size of the population, such as when a population declines because it has exceeded the amount of resources available to support it. Density-dependent mortality can occur through several mechanisms, such as direct competition for limited food and habitat and changes in the foraging activity of predators. With salmon and steelhead, density-dependent mortality can occur at any stage in the animal's life cycle and may be exacerbated by the introduction of large numbers of hatchery fish released over a relatively short period of time, or by the cumulative effects of such releases on natural-origin salmon.[3]

How much density-dependent mortality is taking place in the estuary compared to in the ocean is unclear. There is some evidence that density-dependent mortality is occurring in the open ocean. For example, during years when salmon are especially numerous in the ocean, their growth rates are reduced (Peterman 1984 as cited in Ford 2007). One study found that, during years when nearshore ocean productivity was low, survival of wild Snake River Chinook decreased as releases of hatchery Chinook increased (Levin et al. 2001 as cited in Ford 2007). However, another study found no connection between ocean conditions and density-dependent mortality, which appeared to be occurring among wild Snake River Chinook as hatchery steelhead were released (Levin and Williams 2002 as cited in Ford 2007). The authors suggested that the apparent density-dependent mortality could be better explained by interactions in the tributaries or estuary than by interactions in the ocean.

There is growing awareness among scientists studying the Columbia River estuary that mechanisms related to density dependence may limit salmon and steelhead while they are using estuary and plume habitats. Scientists studying Skagit River fall Chinook have documented density dependence-related mortality as a result of loss of habitat in the Skagit estuary and believe that such mortality can be attributed to a 75 percent loss of tidal delta estuarine habitat (Beamer et al. 2005). With similar habitat losses in the Columbia River estuary, it is possible that too many fish are competing for limited habitat and associated resources in the estuary at key times, and that the resulting stressors translate into reduced salmonid survival. The NMFS Northwest Fisheries Science Center currently is investigating potential density-dependent mortality in the estuary. The "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan" raised the specter of density dependence in the estuary and recommended continued research to analyze conditions there (Northwest Power and Conservation Council 2004). Thus, although the occurrence of density dependence-related mortality in the Columbia River estuary has not been proven, given the dramatic changes in habitat opportunity and capacity in the estuary over the last 200 years, it is likely that some of the mortality associated with the limiting factors described in this chapter is related to increased density of juveniles in the estuary.

[3] It is also possible that inverse density dependence processes occur in some situations. For example, large numbers of adult salmon could swamp marine mammal predators at Bonneville Dam, and the adult survival rates could be higher than in scenarios with smaller numbers of adult fish.

Consistent with this concern, the NMFS Northwest Region Salmon Recovery Division and Northwest Fisheries Science Center are working to better define and describe the scientific uncertainty associated with ecological interactions between hatchery-origin and natural-origin salmon in freshwater, estuarine, and nearshore ocean habitats. Needs include an assessment of the state of the science to help identify priority research on the ecological interactions between hatchery-origin and natural-origin salmon in these habitats and to better define the ecological risks of such interactions. A conference on ecological interactions between hatchery-origin and natural-origin salmon held in May 2010 in Portland, Oregon, contributed to describing the state of the science on these interactions. Conference proceedings will be published and priority research needs identified. Follow-up workshops will help refine the assessment, develop specific research plans, and identify funding sources.

The estuary recovery plan module assumes that density-dependent mortality that may be occurring in the estuary is manifested in part through limiting factors related to habitat availability, competition for food and space, disease, and predation. Given the uncertainty about the mechanisms and effects of density dependence in the estuary, density dependence itself is not included as a limiting factor in the module. Neither are the effects of hatchery fish. Although it is likely that hatchery fish influence the estuarine survival of naturally produced fish (possibly through mechanisms of competition, predation, and disease transfer), the focus of this estuary recovery plan module is the effects of habitat conditions and processes in the estuary and plume, rather than the effects of hatchery or harvest practices. But the degree of density-dependent mortality occurring in the estuary, the role of large releases of hatchery fish, and the cumulative impact of hatchery releases on density-dependent mechanisms are worth exploring through further research.

# Habitat-Related Limiting Factors

Salmonid populations exhibit diverse strategies that guide them through various habitats and ecosystems in specific sequences and patterns. If those sequences and patterns are interrupted, increased mortality may result. Thus, mismatches between the needs of salmonid populations and the availability of habitats to meet those needs can limit salmonid performance in the estuary and plume. The member/vagrant theory discussed in Chapter 2 underscores the need to consider relationships between ESUs' life history strategies and the quality, quantity, and availability of habitats in the estuary and other ecosystems that are interconnected via the salmon and steelhead's complex life cycle.

The habitats that salmonids occupy during their residency in the estuary and plume are formed through the interaction of ocean forces, land, and river flow (Fresh et al. 2005). Flows entering the estuary govern the general availability of habitats, along with sediment transport, salinity gradients, and turbidity, which are themselves aspects of habitat or habitat formation. Over the last 200 years, the magnitude, timing, and frequency of flows have changed significantly, with corresponding effects on the formation and availability of salmonid habitats. Some habitat has been removed, which has reduced the total acreage of the estuary by approximately 15 percent (Fresh et al. 2005). In other cases, particular habitat types have been transformed into other habitat types, and the resulting mosaic of habitats may not be meeting the needs of salmonids as well as the historical pattern of habitats did. For example, approximately 77 percent of historical tidal swamp has been lost (Northwest

Power and Conservation Council 2004), while other shallow-water habitats have increased significantly. The loss of tidal swamps and other forested or vegetated wetlands represents a loss of habitat that ocean-type salmonids use during their estuarine residence. In short, habitat opportunity and capacity have been degraded in the estuary and plume, and alterations in flow have contributed significantly to losses in in-channel, off-channel, and plume habitat. An accurate accounting of specific habitat type changes from pre-European settlement to the present day has not been initiated estuarywide. This measurement of change is important to guiding restoration priorities and represents a significant data gap in the estuary.

An important goal of this estuary recovery module is to describe the various habitats and limiting factors that both ocean- and stream-type juvenile salmonids encounter in the Columbia River estuary and plume. However, current scientific understanding of how stream-type juveniles use the various habitats they encounter in the estuary and plume is less robust than what is known about ocean types' habitat use. To fill this important knowledge gap, the NMFS Northwest Fisheries Science Center and others are exploring how stream-type juveniles expressing all the different possible life history strategies use individual estuarine habitats.

***Affected salmonids:*** Because of their longer estuary residence times and tendency to use shallow-water habitats, ocean-type ESUs are more affected by flow alterations that structure habitat and/or provide access to wetland or floodplain areas than are stream-type ESUs. Stream types have relatively short estuary residence times and use the plume much more extensively than ocean types do. Thus stream-type salmonids are affected by habitat elements such as the shape, behavior, size, and composition of the plume (Fresh et al. 2005).

## Reduced In-Channel Habitat Opportunity

In-channel habitat opportunity in the estuary is a function of the size of river flows, the timing of river flows, incoming and outgoing tides, and the amount and patterns of sediment accretion. Together, tidal action, river flow, and sediment movement create a constantly changing mosaic of channel habitats as water levels rise and fall, sands shift, and salinity gradients move in response to tides. To support salmonids, the various habitats in the estuary need to be connected both spatially and in time. With twice-daily tidal fluctuations, areas that are accessible at one point during the day can be inaccessible 6 hours later or can trap salmonids, exposing them to higher water temperatures and lower dissolved oxygen levels that can result in stress or mortality. Changes in both flow and sediment transport have reduced in-channel habitat opportunity.

**Limiting Factor: Flow-Related Estuary Habitat Changes.** The ability of juvenile salmon to access and benefit from habitat depends greatly on instream flow (Fresh et al. 2005). Changes in the quantity and seasonality of flows in the estuary have a direct bearing on whether key habitats are available to salmonids, when and how long those habitats are available, and whether and how they connect with other key habitats. In addition, juvenile salmonids have physiological or behavioral traits that set the timing for their transformation to saltwater, and changes in flows may interrupt this timing.

Both the quantity and timing of instream flows entering the Columbia River estuary and plume have changed from historical conditions (Fresh et al. 2005). Jay and Naik (2002)

reported a 16 percent reduction of annual mean flow from 1878 to the present and a 44 percent reduction in spring freshet flows. Jay and Naik also reported a shift in flow patterns in the Columbia to 14 to 30 days earlier in the year, meaning that spring freshets are occurring earlier in the season.[4] In addition, the interception and use of spring freshets (for irrigation, reservoir storage, etc.) have caused increased flows during other seasons (Fresh et al. 2005). These changes in the volume and timing of Columbia River flow are limiting factors for salmon and steelhead and have affected habitat opportunity and capacity in the estuary and plume. It is likely that global climate change will contribute to further flow-related changes in estuary habitat. However, changes in flow entering the estuary as a result of climate change are expected to be less than those caused by construction of the hydrosystem (Independent Scientific Advisory Board 2007).

**Limiting Factor: Sediment/Nutrient-Related Estuary Habitat Changes.** The transport of sediment is fundamental to habitat-forming processes in the estuary through sediment deposition and erosion (Fresh et al. 2005). An estuary's form is altered primarily through the deposition of sediment—either sediment that is reworked from other parts of the estuary or sediment that enters the estuary from the watersheds or ocean. Sediment moves among each of the components within the estuary, allowing the estuary as a whole to continually be adjusting toward some long-term equilibrium form in response to changes in physical or geomorphic processes (Philip Williams & Associates and Farber 2004). Sediment from the estuary and upstream sources also affects the formation of nearshore ocean habitats north and south of the Columbia River entrance.

Since the late nineteenth century, sediment transport from the interior basin to the Columbia River estuary has decreased about 60 percent and total sediment transport has decreased about 70 percent (Jay and Kukulka 2003). This reduction in the amount of sediment transport in the Columbia River has affected habitat-forming processes in the estuary and plume (Bottom et al. 2005) and is presumed to be a limiting factor for salmon and steelhead because it limits the accretion of sediment and thus the formation of shallow-water habitats. Although the consequences of the reduced transport of sediment through the estuary and plume are not fully understood, the magnitude of change is very large compared to historical benchmarks (Fresh et al. 2005).

Sediment also provides important nutrients that support food production in the estuary and plume. Microdetrital food particles adhere to sediment suspended in the water column, making different food sources available to different species than was the case historically. Currently, organic matter associated with fine sediments supplies the majority of estuarine secondary productivity in the food web (Simenstad et al. 1984 as cited in Northwest Power and Conservation Council 2004).

## Reduced Off-Channel Habitat Opportunity

Columbia River access to its historical floodplain is an important factor for rearing ocean-type juvenile salmonids. Stream-type juvenile salmonids also are believed to benefit from access to off-channel habitats, which support less dominant stream-type life histories and provide food resources for stream types during downstream migration (Bottom et al. 2005).

[4] These analysis were calculated by comparing observed flow (data from a gauge), estimated adjusted flow (observed flow corrected for reservoir manipulations), and estimated virgin flow (estimate of river flow without human alteration).

Historically, flows that topped the river's bank provided juvenile salmonids with access to low-velocity areas in the lower river and estuary that juveniles used as refugia and for rearing; many of these areas were dominated by Sitka spruce tidal swamps, which were an integral component of the estuarine ecosystem. Overbank flows contributed key food web inputs to the ecosystem and influenced wood recruitment, predation, and competition in the estuary (Fresh et al. 2005).

Today, mainstem habitat in the Columbia and Willamette rivers has, in many cases, been reduced to a single channel (Northwest Power and Conservation Council 2004), and channelization of the estuary has eliminated access to an estimated 77 percent of historical tidal swamps (Fresh et al. 2005). In fact, over the past 200 years the surface area of the estuary has decreased by approximately 20 percent (Fresh et al. 2005).

The near elimination of overbank flooding is a function of both reductions in peak freshet flows (as a result of flow regulation for electricity generation, storage for irrigation and municipal use, and flood control) and increases in the bankfull level of the Columbia River (as a result of dikes and levees), among other factors.

Figure 3-1 shows diked areas from the estuary mouth to Bonneville dam. This map was generated from a GIS database developed by the University of Washington, U.S. Geological Survey, and Lower Columbia River Estuary Partnership that provides statistics and maps depicting the historical floodplain, diked areas, dredged material disposal sites, over-water structures, contaminant monitoring sites, and other key features in the estuary. Some of these features are shown in GIS-based reach maps presented in Appendix A.

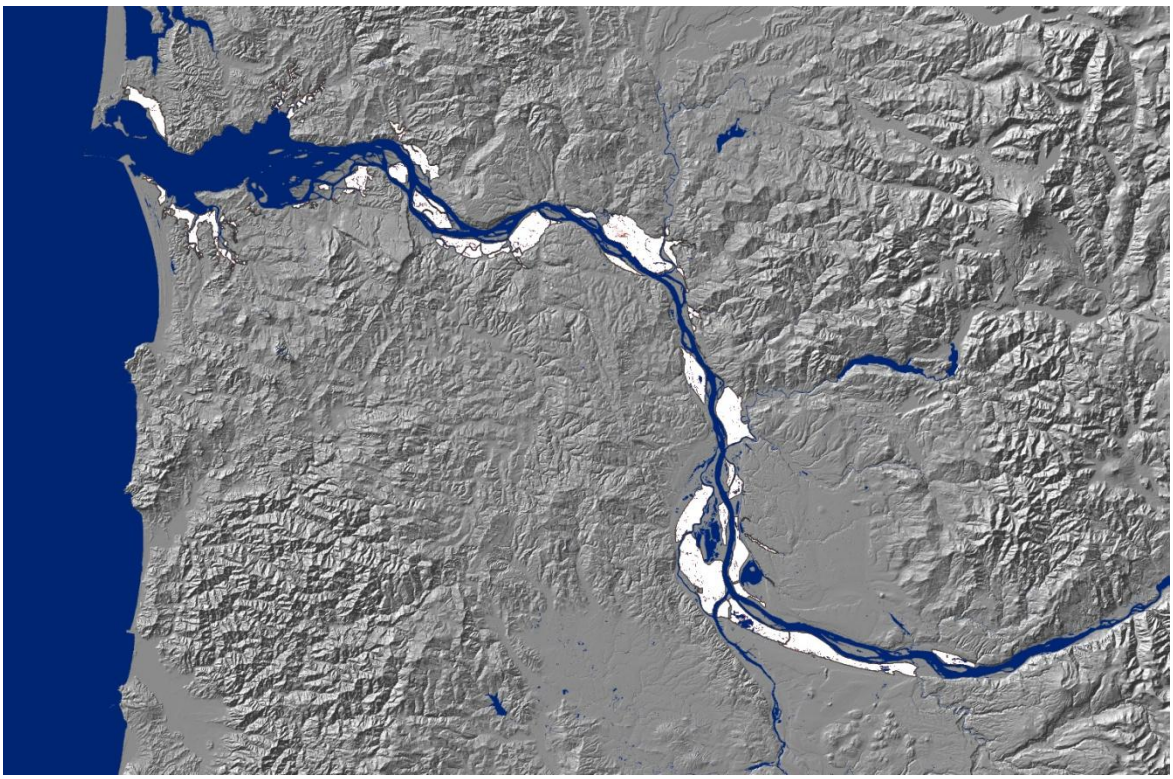

**FIGURE 3-1**
Diked Areas in the Columbia River Estuary
(Source: Lower Columbia River Estuary Partnership 2005.)

**Limiting Factor: Flow-Related Changes in Access to Off-Channel Habitat.** Reduced access to off-channel habitats is a limiting factor for salmon and steelhead because of impacts on food webs and the reduced availability of habitats preferred by fry and fingerlings. Typically, overbank flows were driven by spring freshets, which occurred at the time of year when there was the greatest variety of juvenile salmon and steelhead using the estuary (Fresh et al. 2005). Overbank flows occur much less frequently now than they did historically, in part because climate changes and human alterations have reduced the number of high flows in the Columbia (Jay and Kukulka 2003).

**Limiting Factor: Bankfull Elevation Changes.** The construction of levees also has reduced the frequency of overbank flows because more river water is needed to cause overbank flow. Historically the bankfull level was 18,000 $m^3 s^{-1}$, while today it is 24,000 $m^3 s^{-1}$—fully one-third more. Only five overbank events have occurred since 1948 (Jay and Kukulka 2003). The reduction in overbank events is a limiting factor because it reduces the availability of food and refugia for ocean-type juveniles rearing in the estuary. Less dominant stream-type juveniles are affected in the same manner.

## Reduced Plume Habitat Opportunity

Evidence suggests that the plume supports ocean productivity by increasing primary plant production during the spring freshet period, distributing juvenile salmonids in the coastal environment, concentrating food sources such as icthyoplankton (megalopae, for example) and zooplankton, and providing refugia from predators in the more turbid, low-salinity plume waters (Fresh et al. 2005). Changes in the volume and timing of Columbia River flow have altered both the size and structure of the plume during the spring and summer months (Northwest Power and Conservation Council 2000).

**Limiting Factor: Flow-Related Plume Changes.** For juvenile salmonids preparing for ocean life, the plume is believed to function as habitat, as a transitional saltwater area, and as refugia. As mentioned earlier, stream-type ESUs in particular are affected by the size, shape, behavior, and composition of the plume (Fresh et al. 2005).

Over the past 200 years characteristics of the plume have been altered, and conditions caused by reductions in spring freshets and associated sediment transport processes may now be suboptimal for juvenile salmonids (Casillas 1999). Plume attributes affected by changes in flow include surface areas of the plume, the volume of the plume waters, the extent and intensity of frontal features, and the extent and distance offshore of plume waters (Fresh et al. 2005).

**Limiting Factor: Sediment/Nutrient-Related Plume Changes.** It is believed that the sediment and nutrients transported in the plume fuel salmon productivity in the ocean and provide relief from predation (Casillas 1999). This is particularly true for stream-type ESUs, who use the plume more extensively than ocean types do and thus are more affected when the amount of plume habitat is reduced.

## Limiting Factor: Water Temperature

Higher water temperatures have reduced habitat quality for salmonids that use the estuary during summer months. Since 1938, average summer water temperatures at Bonneville Dam have increased 4° F (2.2° C) (Lower Columbia Fish Recovery Board 2004). Among-year

variability in temperature has been reduced by 63 percent since 1970 (Lower Columbia Fish Recovery Board 2004). As shown in Figure 3-2, temperatures entering the estuary (as measured at Bonneville Dam) have increased steadily since 1938. Temperatures also exceed 20° C (68° F) earlier during the year and more frequently than they did historically (National Research Council 2004).

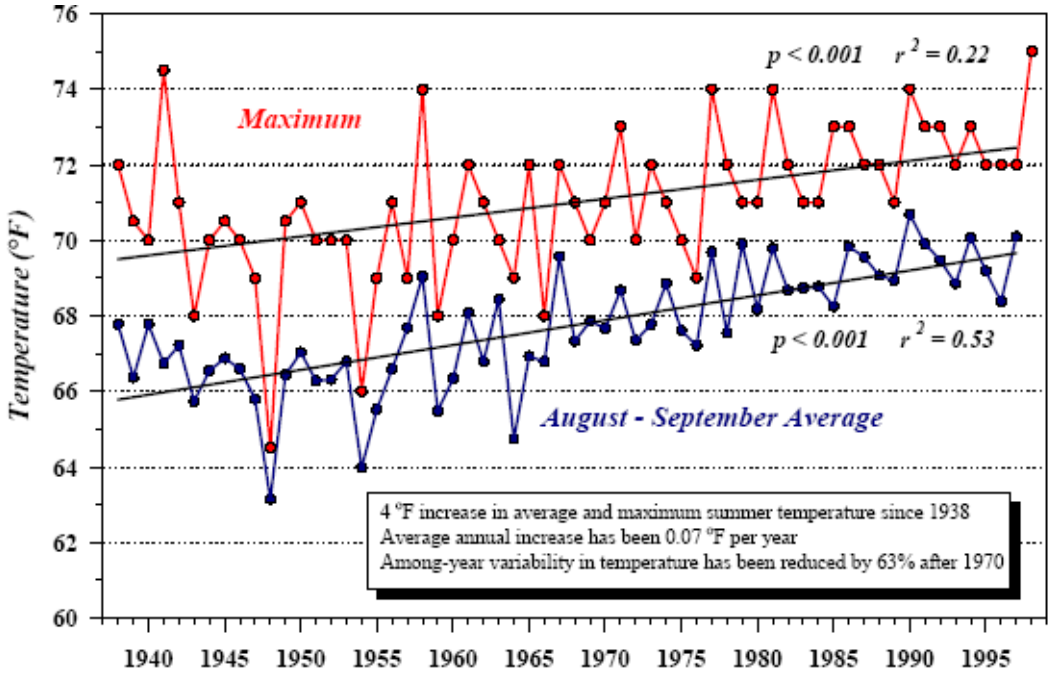


**FIGURE 3-2**
Temperatures of Water Entering the Estuary
(Reprinted from Lower Columbia Fish Recovery Board 2004.)

(Water temperatures of 20° C (68° F) are considered the upper thermal tolerance limit for cold-water species such as salmonids (National Research Council 2004). Pacific salmon can suffer adverse physiological and behavioral effects as a result of persistent, intermittent, or cumulative exposure to high water temperatures, or from increased daily variation in water temperature (McCullough 1999). Temperatures above 18° C (64.4° F) can impair the metabolism, growth, and disease resistance of salmonids, as well as alter the timing of adult migrations, fry emergence, and smoltification (McCullough et al. 2001, Sauter et al. 2001). Other effects of high water temperatures include adult mortality, reduced pre-spawning survival of eggs and sperm, difficulty competing with non-salmonid fish, prevention or reversal of smoltification, and harmful interactions with certain other habitat stressors (Marine 2004, McCullough 1999, Dunham et al. 2001, Materna 2001, McCullough et al. 2001, and Sauter et al. 2001). For example, the toxicity of some contaminants increases at high water temperatures, and levels of dissolved oxygen go down. Adult sockeye have been known to suffer stress and disease as they are exposed to warm water in estuaries, waiting for cool runoff conditions in their natal stream (Independent Scientific Advisory Board 2007). Warmer temperatures may also enhance conditions for warm-water fish that prey on or compete with juvenile salmonids (Independent Scientific Advisory Board 2007) and cause other changes in the estuarine food web.

During the next century, it is likely that global climate change will contribute to continued water temperature rises in the Columbia River basin as precipitation increasingly falls as rain rather than snow, snow pack diminishes, peak flows increase, and late-summer/early-fall flows are reduced (Independent Scientific Advisory Board 2007). (See Chapter 4 for more on the expected effects of global climate change in the Columbia River basin and estuary.)

### Limiting Factor: Stranding

In the estuary, large ships passing through the navigational channel produce bow waves that crash against shorelines in Oregon and Washington. Small ocean-type fry and fingerlings rear within inches of shore and may become stranded as waves intersect the bank and recede (Ackerman 2002), although the extent of this problem is unclear. A 1977 study by Washington Department of Fisheries (WDF) observed 2,397 juvenile salmonids—mostly Chinook—stranded as a result of passage of 216 deep draft vessels (Bauersfeld 1977).

A NOAA technical memorandum (Hinton and Emmett 1994) published in 1994 concluded that the problem was not as significant as documented in the WDF report. Hinton and Emmett found only five juvenile salmonids stranded after observing 145 vessels. A third study, conducted for the U.S. Army Corps of Engineers, observed 21 juvenile Chinook salmon stranded at two sites (Ackerman 2002). In one occurrence, 10 juveniles were stranded by one vessel. As part of the channel deepening project being conducted by the U.S. Army Corps of Engineers, a two-part study of stranding was initiated by the University of Washington and the Portland District of the Corps. The study is designed to measure differences in stranding events before and after channel deepening activities. The first study was published in February 2006 (Pearson et al. 2006). In general, the report documents mortality attributed to stranding events for three test sites; it also builds on other work to determine the conditions that increase the likelihood of stranding events.

Early in 2008, the Port of Vancouver enlisted Entrix, Inc., to perform a spatial analysis of beach susceptibility for the stranding of juvenile salmonids by ship wakes (Pearson 2008). The study examined wave characteristics and the geomorphology of the lower river but did not examine nearshore fish density. The purpose of the study was to estimate the number of miles of shoreline that exhibit traits expected to potentially cause stranding. The study concluded that approximately 33 miles of shoreline between the mouth of the river and the city of Vancouver have shoreline characteristics consistent with stranding (Pearson 2008).

## Food Web-Related Limiting Factors

Energy released from the Columbia River and the ocean converges in the estuarine and plume environments where, combined with the biological energy of primary plant production, it forms the basis for life in the estuarine ecosystem. Ultimately, energy that is transferred through the estuarine food web begins with sunlight; sunlight, minerals, and nutrients lead to plant growth in primary production; plants are eaten by animals and animals are preyed upon by other animals in secondary production; and dead plants, animals, and their material are broken down and re-integrated into the base of the food web. Salmon and other native species have evolved together in response to the basic inputs of energy and their circulation through the ecosystem. The result has been the development of an intricately structured food web in the estuary that encompasses food sources, food

availability, and inter- and intra-species relationships. Alterations in any one of the elements of the food web, such as food sources or availability, can ripple throughout the ecosystem, reducing habitat capacity and having potentially far-reaching effects on salmonids and other species.

As part of the food web, decomposing materials known as detritus are consumed by juvenile salmonids, either directly or indirectly through other organisms that feed on the detritus (Northwest Power and Conservation Council 2004). There is evidence that a shift in the food base of the estuary—from macrodetrital to microdetrital—has significantly changed the food web and that complex inter- and intra-species relationships have been permanently altered (Northwest Power and Conservation Council 2004). Microdetrital sources favor production of planktonic copepods and other deep-water organisms that are not typically consumed by juvenile salmon (Bottom et al. 2005). Juvenile salmon that rear extensively in the estuary preferentially consume invertebrates from shallow-water and vegetated habitats, where decomposing plant tissue from emergent plants in estuarine wetlands creates macrodetritus (Bottom et al. 2005). Reductions of wetland and foraging habitat, simplification of habitats, and altered sediment inputs have contributed to the changes in detrital sources in the estuary. By disrupting the food web, these conditions have increased competition and predation (Bottom et al. 2005).

Most studies of prey preferences of juvenile salmon using the estuary focus on stream-type fish, which are less likely than ocean types to rear in estuarine habitats for extended periods. Studies that focus on ocean-type salmonids demonstrate that juvenile salmon appear to feed selectively within particular regions of the estuary (Bottom et al. 2005). In freshwater and brackish habitats, juvenile salmon feed extensively on emergent insects such as chironomids (midges) and epibenthic crustaceans such as mysid shrimp and gammarid amphipods (Macneale et al. 2009 and Miller and Simenstad 1997). Farther downstream in higher salinity portions of the estuary, salmon consume epibenthic crustaceans such as gammarid amphipods and harpaticoid copepods (Bottom et al. 2005). According to a University of Washington master's thesis that demonstrated the importance of midge insects in the diet of juvenile Chinook salmon occupying shallow-water habitats in the Columbia River estuary, emerging chironomids were the dominant prey for Chinook of all sizes (Lott 2004). Additionally, the Oregon Department of Fish and Wildlife found migrating yearling Chinook actively feeding on daphnia. The same study found subyearling Chinook and coho feeding on daphnia year-round in the lower Willamette River (Friesen 2005).

***Affected salmonids:*** Ocean-type ESUs are more likely than stream-type juveniles to be affected by food web alterations because of their use of estuary habitats and their longer residency times. Stream-type ESUs are more influenced in the plume environment because of reduced fine-sediment inputs leaving the estuary.

## Food Source Changes

As described below, changes in the detrital sources that form the base of the estuarine food web have been significant and represent a limiting factor for salmonids. Figure 3-3 shows a conceptual model of the estuary food web developed by the U.S. Army Corps of Engineers. The historical tidal marsh macrodetritus-based food web is displayed at the top of Figure 3-3, while the current food web, which is based on imported microdetritus, is shown at the bottom.

**Limiting Factor: Reduced Macrodetrital Inputs.** The estuarine food web formerly was supported by macrodetrital inputs that originated from emergent, forested, and other wetland rearing areas in the estuary (Northwest Power and Conservation Council 2004). Today, detrital sources from emergent wetlands in the estuary are approximately 84 percent less than they were historically (Bottom et al. 2005). The reduction of macrodetritus in the estuary reduces the food sources for juvenile salmonids. As a result, juveniles may have reduced growth, lipid content, and fitness prior to ocean migration or may need to reside longer in the estuary.

Macrodetrital plant production has declined as a result of the construction of revetments along the estuary shorelines, the disposal of dredged material in what formerly were shallow or wetland areas where plant materials or insects could drop into the water, simplification of habitat through the removal of large wood, and reductions in flow. Flow reductions affect detrital sources by limiting the amount and availability of wetlands—areas that normally would be contributing macrodetritus to the food web—and cutting the number of overbank flows. Historically, much of the detrital inputs occurred during overbank events, which provided additional shallow-water habitat for juvenile salmonids and resulted in significant detrital inputs to the estuary. As mentioned earlier, overbank events occur much less frequently today than they did historically.

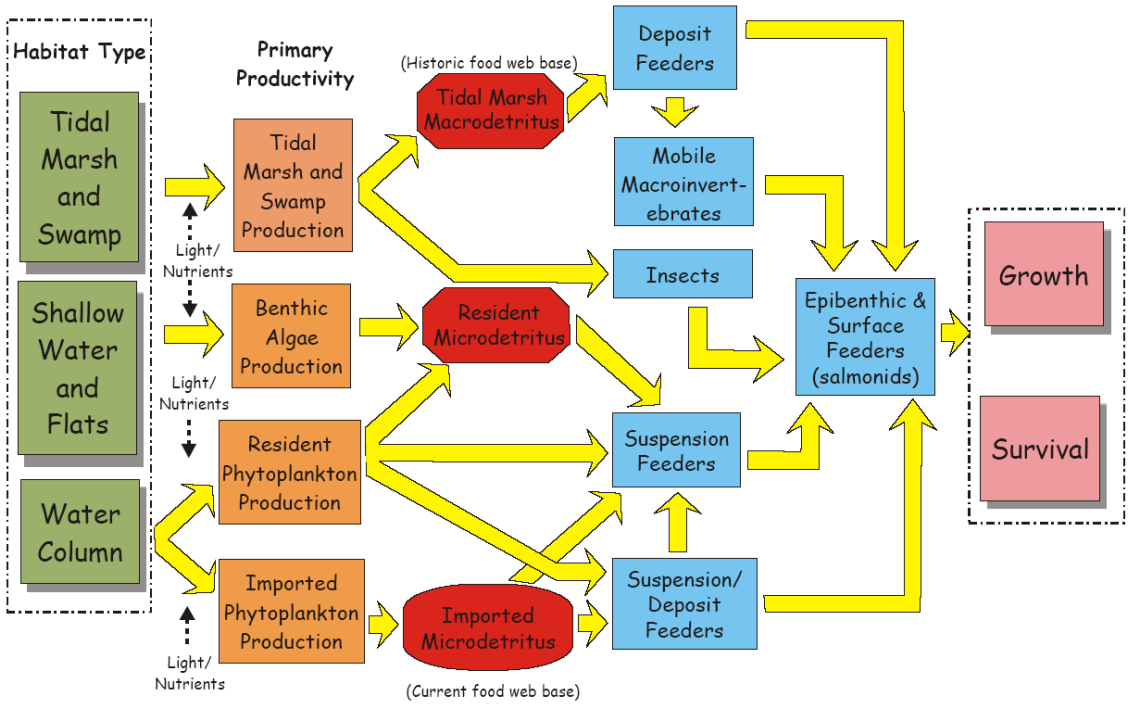


**FIGURE 3-3**
Conceptual Model of the Columbia River Estuary Food Web

**Limiting Factor: Increased Microdetrital Inputs**. The current food web is based on decaying phytoplankton delivered from upstream reservoirs and nutrient inputs from urban, industrial, and agricultural development. The amount of this microdetritus has increased dramatically (Bottom et al. 2005). The switch in the estuarine food web from a

macrodetritus-based source to a microdetritus-based source has altered the productivity of the estuary (Bottom et al. 2005).

The substitution of detrital sources in the estuary also has contributed to changes in the spatial distribution of the food web (Bottom et al. 2005). Historically the macrodetritus-based food web was distributed evenly throughout the estuary, including in the many shallow-water habitats favored by ocean-type salmonids. But the contemporary microdetrital food web is concentrated within the estuarine turbidity maximum in the middle region of the estuary (Bottom et al. 2005). This location is less accessible to ocean-type ESUs that use peripheral habitats and more accessible to species such as American shad that feed in deep-water areas.

Pelagic fish such as shad may also benefit from the fact that the estuarine turbidity maximum traps particles and delays their transport to the ocean up to 4 weeks, compared to normal transport of around 2 days (Northwest Power and Conservation Council 2004). The estuarine turbidity maximum is thought to contain bacteria that attach to detritus. Together these represent the primary food source in the estuary today (Northwest Power and Conservation Council 2004).

## Competition and Predation

Predation and competition for habitat and prey resources limit the success of juvenile salmonids entering the estuary and plume. Both spatial and energetic losses can involve either density-dependent or density-independent processes (Bottom et al. 2005). Spatial and temporal losses of habitat and large pulses of hatchery juveniles may, under some conditions, result in density-dependent salmonid mortality (Bottom et al. 2005).

Competition among salmonids and between salmonids and other fish may be occurring in the estuary (Lower Columbia Fish Recovery Board 2004), with the estuary possibly becoming overgrazed when large numbers of ocean-type salmonids enter the area. Food availability may be reduced as a result of the temporal and spatial overlap of juveniles from different locations (Bisbal and McConnaha 1998 as cited in Lower Columbia Fish Recovery Board 2004).

Ecosystem-scale changes in the estuary have altered the relationships between salmonids and other fish, birds, and mammal species, both native and exotic. Some native species' abundance levels have decreased from historical levels—perhaps to the point of extinction—while others have increased to levels far exceeding those in recorded history, with associated changes in predation of salmon and steelhead juveniles.

The presence of non-indigenous fish, invertebrates, and plants in species assemblages indicates major changes in aquatic ecosystems (Northwest Power and Conservation Council 2004). Globally the introduction of such species is increasing, a fact that is attributable to the increased speed and range of world trade, which facilitates the transport and release—whether intentional or not—of non-indigenous species (Northwest Power and Conservation Council 2004). In the estuary, the introduction of exotic species has altered the ecosystem through competition, predation, disease, parasitization, and alterations in the food web.

Non-native species affect ocean-type ESUs more than they do stream-type ESUs because of the ocean types' longer juvenile estuary residency times and use of shallow-water habitats.

**Limiting Factor: Native Fish**. The northern pikeminnow is a native piscivorous fish that preys on juvenile salmonids in the estuary. Although pikeminnows have always been a significant source of mortality for juvenile salmonids in the Columbia River, changes in physical habitats may have created more favorable conditions for predation (Northwest Power and Conservation Council 2004). These changes include reduced flows and favorable micro-habitats formed by pilings, pile dikes, and other over-water structures. The diet of pikeminnows varies with age, with the largest adults representing the biggest risk to juvenile salmonids. Both ocean-type ESUs and stream-type ESUs are affected, but for different reasons. Ocean-type juveniles are susceptible because of their longer estuary residency times and use of shallow-water habitats. Stream-type juveniles are susceptible because they are leaving faster, deeper water to forage for food in shallow areas that are frequented by pikeminnow.

**Limiting Factor: Native Birds.** As a result of estuary habitat modifications, the number and/or predation effectiveness of Caspian terns, double-crested cormorants, and a variety of gull species has increased (Fresh et al. 2005). In 1997 it was estimated that avian predators consumed 10 to 30 percent of the total estuarine salmonid smolt production in that year (Northwest Power and Conservation Council 2004). The 2007 season summary of *Research, Monitoring, and Evaluation of Avian Predation on Salmonid Smolts in the Lower and Mid-Columbia River* (Roby et al. 2008) estimates that 5.5 million juvenile salmonids were consumed by terns in 2007. Stream-type juvenile salmonids are most vulnerable to avian predation by Caspian terns because the juveniles use deep-water habitat channels that have relatively low turbidity and are close to island tern habitats (Roby et al. 2008). Double-crested cormorants are estimated to have consumed an average of 7 million juvenile salmonids annually over the years 2001 to 2009. Cormorant predation has increased in the past several years and has been as high as 11 million, in 2009 (Fredricks 2010).

**Limiting Factor: Native Pinnipeds.** The abundance of native pinnipeds has steadily increased since passage of the Marine Mammal Protection Act in 1972. Harbor seals, Steller sea lions, and California sea lions all prey on salmon and steelhead in the estuary (Northwest Power and Conservation Council 2004). Diet studies indicate that pinnipeds consume both juvenile and adult salmonids. U.S. Army Corps of Engineers' annual estimates of adult mortality that occurs at Bonneville Dam because of pinnipeds (primarily California sea lions) ranged from 0.4 percent (2002) to 4.2 percent (2007) during the study period ending in 2010 (U.S. Army Corps of Engineers 2010).[5] Other, radio telemetry-based studies suggest that annual pinniped predation on spring Chinook and winter steelhead at Bonneville Dam may be as high as 8.5 percent and 20 percent, respectively (NMFS 2008b, Appendix G). These estimates do not account for pinniped mortality occurring downstream of Bonneville Dam. There are no official estimates of downstream mortality on adult spring Chinook and winter steelhead (both of which are stream-type salmonids); however, unsubstantiated estimates are as high as 10 percent.

**Limiting Factor: Exotic Fish.** At least 37 exotic fish species are now found in the Columbia River estuary (Northwest Power and Conservation Council 2004). American shad were introduced into the Columbia River in the 1880s, and adult returns now exceed 4 million in

[5] Estimated consumption of adult salmonids ranged from a low of 1,010 in 2002 to a high of 6,081 in 2010; the percent of run consumed varied among reporting years because of changes in run size.

a single year (Northwest Power and Conservation Council 2004). While shad do not eat salmonids, they exert tremendous pressure on the estuary food web given the sheer weight of their biomass. Some evidence suggests that planktivorous American shad have an impact on the abundance and size of *Daphnia* in Columbia River mainstem reservoirs (Haskell et al. 2006 in Independent Scientific Advisory Board 2008), thereby reducing this important food source for subyearling fall Chinook. Other exotic fish in the estuary, such as smallmouth bass, walleye, and catfish, are piscivorous; however, their abundance levels are relatively small.

**Limiting Factor: Introduced Invertebrates.** Twenty-seven non-native invertebrate species have been observed in the estuary and documented by the Lower Columbia River Aquatic Non-indigenous Species Survey (Sytsma et al. 2004). Surveys have documented that the estuarine copepod community has changed from a system dominated by a single introduced species, *Pseudodiaptomis inopinus*, to a system dominated by two newly introduced Asian copepods: *Pseudodiaptomis forbesi* and *Sinoclaanus doerri* (Santen 2004). In some cases, the abundance of non-native invertebrates can alter food webs through their wide distribution and key role in the food chain (Northwest Power and Conservation Council 2004).

**Limiting Factor: Exotic Plants.** The introduction of non-indigenous plant species also has altered the estuary ecosystem. Exotic plant species often out-compete native plants, which results in altered habitats and food webs (Northwest Power and Conservation Council 2004). About 18 aquatic plants have been introduced into the estuary since the 1880s (Sytsma et al. 2004). Examples of non-indigenous plant species include purple loosestrife, Eurasian milfoil, parrot feather, and Brazilian elodea. In addition to out-competing native plants, introduced plant species can contribute to poor water quality and create dense, monospecific stands that represent poor habitat for native species (Northwest Power and Conservation Council 2004). In turn, these new plant communities may alter insect and detritus production in and around vegetated wetlands.

# Toxic Contaminants

The quality of habitats and the food web in the Columbia River estuary is degraded as a result of past and current releases of toxic contaminants (Fresh et al. 2005, Lower Columbia River Estuary Partnership 2007), from both estuary and upstream sources. Historically, levels of contaminants in the Columbia River were low, except for some metals and naturally occurring substances (Fresh et al. 2005). Today, contaminant levels in the estuary are much higher, as the estuary receives contaminants from more than 100 point sources and numerous non-point sources, such as surface and stormwater runoff from agricultural and urban sources (Fuhrer et al. 1996). With the cities of Portland, Vancouver, Longview, and Astoria on its banks, the Columbia River below Bonneville Dam is the most urbanized section of the river. In 2000, Portland Harbor was placed on the National Priorities List, which designates Superfund sites. Sediments in the river at Portland Harbor are contaminated with various toxic compounds, including metals, PAHs, PCBs, chlorinated pesticides, and dioxin (Oregon Department of Environmental Quality 2008). Work in recent decades has detected contaminants in aquatic insects, resident fish species, salmonids, river mammals, and osprey, reinforcing that contaminants are widespread throughout the estuary's food web (Tetra Tech 1996, Fuhrer et al . 1996, Lower Columbia River Estuary Partnership 2007).

Depending on concentration, exposure to toxic contaminants can kill aquatic organisms outright or have sublethal effects that compromise their health and behavior. Sublethal concentrations of contaminants affect the survival of aquatic species by increasing stress, decreasing fitness, predisposing organisms to disease, delaying development, and disrupting physiological processes such as reproduction and smoltification.

Acute lethal effects of toxic contaminants, such as fish kills in response to accidental discharges or spills, have been reported but are generally rare. However, research by the NMFS Northwest Fisheries Science Center has revealed some notable exceptions in which toxic contaminants may lead to the direct mortality of salmonids, such as the following situations:

- Coho pre-spawn mortality. For the past several years, NMFS has been documenting the recurrent die-offs of adult coho salmon returning to spawn in restored lowland urban streams in the Puget Sound Basin, at rates ranging from 30 to 90 percent of local coho runs (McCarthy et al. 2008). The weight of evidence to date suggests that pollutants in runoff from urban landscapes are causing the fish kills, and the phenomenon is correlated with high densities of roads and vehicle traffic. Based on findings from Puget Sound, coho spawners are likely at risk in urbanizing watersheds in the greater Columbia Basin (particularly the lower Columbia River).

- Synergistic toxicity of pesticide mixtures. A study by NMFS, in collaboration with Washington State University, has shown that common current-use pesticides (organophosphate and carbamate insecticides) produce unexpectedly synergistic toxicity and death in juvenile salmon following short-term exposure (Laetz et al. 2007). These agricultural pesticides are used in most of the major subbasins, and they reach rearing and migration habitats for salmon via spray drift, surface runoff, and irrigation return flows. In a 10-year study by the U.S. Geological Survey, Gilliom (2007) found that mixtures of pesticide compounds are prevalent in streams in watersheds that are dominated by agricultural, urban, or mixed land use.

- Salmon egg mortality. Increased mortality has been observed in salmon eggs exposed to PAHs in oil, such as at sites in Alaska following the Exxon Valdez oil spill (Heintz et al. 1999, Carls et al. 2005). An unpublished study by NMFS suggests that salmon embryos incubated in urban stream water also show relatively high rates of developmental defects and mortality when compared to embryos raised in the same water passed though an in situ streamside filtration system. At this time, the contaminants in the urban stream water are unidentified contaminants that are toxic to salmon embryos and likely pose an important early life stage threat to salmon in urbanizing watersheds.

Although the lethal effects described above are of concern, sublethal effects of contaminants are probably the greatest threat to juvenile salmon in the Columbia River. In juvenile salmonids, contaminant exposure can result in decreased immune function and generally reduced fitness (Northwest Power and Conservation Council 2004, Arkoosh and Collier 2002). Exposure can also impair growth, development, and reproduction and disrupt olfaction; salmonids depend on olfaction for migration, imprinting on natal streams, homing, and detecting predators, prey, potential mates, and spawning cues. These sublethal effects of contaminant exposure may indirectly increase mortality from other factors like

infectious disease, parasites, predation, exhaustion, and starvation by suppressing salmonid immune systems and impairing necessary behaviors such as swimming, feeding, responding to stimuli, and avoiding predators (Lower Columbia River Estuary Partnership 2007). Contaminants that affect growth can have significant effects. Juvenile growth is necessary for ocean survival (Zabel and Williams 2002 as cited in Lower Columbia River Estuary Partnership 2007), and adult fish size has been correlated to reproductive success and egg size (Healey and Heard 1983, Beacham and Murray 1987). Low lipid content, which has been observed in outmigrating juvenile Chinook salmon in the Columbia River estuary (Johnson et al. 2007b, Lower Columbia River Estuary Partnership 2007), is another sign of poor growth that is correlated with an increased risk of juvenile mortality (Biro et al. 2004). Thus, toxic contaminants that impair salmonid growth can reduce juvenile survival, adult returns, and individual reproduction. Although many effects of contaminants require an exposure period of weeks to months, some impacts, especially those on behavior, can occur very quickly. For example, effects of pesticides and copper on the salmon olfaction system can be seen after exposure periods of only a few hours (Sandahl et al. 2004 and 2007, Hecht et al. 2007).

Toxic contaminants can also indirectly affect salmon via the food web, especially prey such as aquatic and terrestrial insects. Insect bodies accumulate contaminants, which salmon in turn ingest when they consume insects. Additionally, many toxic contaminants are specifically designed to kill insects and plants, reducing the availability of insect prey or modifying the surrounding vegetation and habitats. The availability of prey species is one of the primary determinants of salmonid growth, and reductions in the prey base can affect salmonid survival and productivity (Chapman 1966 and Mundie 1974 as cited in Lower Columbia River Estuary Partnership 2007). Changes in vegetative habitat can shift the composition of biological communities; create favorable conditions for invasive, pollution-tolerant plants and animals; and further shift the food web from macrodetrital to microdetrital sources.

A study by Loge et al. (2005) in the Columbia River will likely bring more attention to the effects of contaminants on salmonids in the estuary. The study documents infectious disease in outmigrating juvenile salmonids attributed to abiotic stressors, such as chemicals, that influence host susceptibility to infection. The study estimates disease-induced mortalities in Chinook salmon related to exposure to contaminants at 1.5 percent and 9 percent for estuary residence times of 30 to 120 days, respectively (Loge et al. 2005).

Other contaminants, including endocrine-disrupting substances such as synthetic hormones, are beginning to be characterized in the estuary, and these contaminants could have substantial effects on salmon and steelhead (Fresh et al. 2005). A study by the Lower Columbia River Estuary Partnership, aided by NMFS and the U.S. Geological Survey, found emerging contaminants such as caffeine, acetaminophen, and human and veterinary antibiotics in the water column of the estuary and evidence of exposure to estrogenic compounds in the blood of juvenile Chinook salmon (Lower Columbia River Estuary Partnership 2007). Several suspected hormone disruptors were detected in the water column, including bisphenol A (a plasticizer), HHCB (a synthetic musk), and polybrominated diphenyl ethers (PBDEs, which are synthetic flame retardants used in everyday products like plastic, cushions, and fabrics). Although some forms of PBDEs have been banned, PBDE concentrations in the environment have increased exponentially during

recent decades. In the Columbia River estuary, they have been found in the water column, on suspended sediment, and in the tissue and stomach contents of juvenile Chinook salmon, which indicates that salmon prey also are contaminated (Lower Columbia River Estuary Partnership 2007). PBDEs are similar to PCBs in their chemical structure and sublethal effects, such as neurotoxicity and hormone disruption.

***Affected salmonids:*** Contaminant exposure by stream-type and ocean-type salmon likely reflects contaminants present in rearing habitats. Stream-type salmon are apt to have contaminant loads that reflect conditions in the upper Columbia River and its tributaries, while ocean-type salmon are apt to have loads that reflect conditions in the lower river and estuary (Leary et al. 2006, Johnson et al. in prep, Dietrich et al in prep a). It is likely that both stream-type and ocean-type juvenile salmonids are affected by short-term exposure to waterborne contaminants such as organophosphate pesticides and dissolved metals that can have acute effects on salmon olfactory function and behavior (Fresh et al. 2005, Johnson et al. in prep a), and both types could be affected by bioaccumulative legacy pesticides, such as DDTs, that are present throughout the Columbia Basin. Additionally, ocean-type juveniles likely experience adverse effects and possibly mortality from urban and industrial bioaccumulative toxics such as PCBs and PBDEs that are present in the Columbia River estuary and are absorbed during longer estuarine residence times (Fresh et al. 2005). Both life history types could be affected by contaminant impacts on prey resources (Johnson et al. in prep). Preliminary data tend to support the hypothesis that contaminant body burdens are generally higher in ocean-type stocks than in stream-type stocks (Johnson et al. 2007a) and higher in outmigrating subyearling Columbia River Chinook than in yearlings, especially for industrial contaminants such PCBs and PBDEs that are present at higher concentrations in the Columbia River estuary (Lower Columbia River Estuary Partnership 2007, Dietrich et al. 2008). However, more work is needed on contaminant uptake and impacts on salmon of different stocks and life history types.

**Limiting Factor: Bioaccumulation Toxicity.** Bioaccumulative and potentially toxic waterborne contaminants, trace metals, and chlorinated compounds have been observed in the estuary (Fuhrer et al. 1996, Fresh et al. 2005, Lower Columbia River Estuary Partnership 2007). DDT and PCBs have been detected in juvenile salmon from the estuary at concentrations above threshold levels for health effects, and in salmon stomach contents and water quality samples from sites throughout the estuary (Lower Columbia River Estuary Partnership 2007). DDT, PCBs, and trace metals such as copper all bioaccumulate and concentrate in animals near the top of the food chain.

Loge et al. (2005) estimated disease-induced, contaminant-related mortalities at 1.5 percent and 9 percent for juvenile Chinook residing in the Columbia River estuary for 30 to 120 days, respectively (Loge et al. 2005). Figures 3-4 and 3-5 show concentrations of PCBs and DDTs found in the stomach contents of subyearling fall Chinook in several locations of the Columbia River estuary, other Pacific Northwest sites, and hatcheries.

**Limiting Factor: Non-Bioaccumulative Toxicity.** A variety of organochlorines (including trichlorobenzene, the insecticides aldrin and dieldrin, and PAHs) in the estuary are above state and Federal guidance levels (Northwest Power and Conservation Council 2004). These contaminants tend not to bioaccumulate in salmon and steelhead (although PAHs do bioaccumulate in invertebrates), but they are readily absorbed and can have sublethal

effects. Copper also was detected in juvenile salmon, at concentrations that can impair olfaction (Lower Columbia River Estuary Partnership 2007). In addition, copper can interact with other toxic contaminants—mercury, aluminum, iron, and certain pesticides—to cause synergistic effects, such that the combined toxicity is greater than the toxicity predicted based on the sum of the contaminants present (Eisler 1998 as cited in Lower Columbia River Estuary Partnership 2007).

As mentioned above, sublethal concentrations of contaminants can affect the survival of aquatic species by increasing stress, predisposing organisms to disease, delaying development, and disrupting physiological processes (Northwest Power and Conservation Council 2004). Exposure to PAHs may be a particular problem for salmon in the urbanized portions of the estuary, as these contaminants are very common in stormwater as well as in industrial discharges. Although salmonids can break down PAHs, the metabolites of PAHs can be mutagenic and carcinogenic, especially in cases of chronic exposure. PAHs also can contribute to immune dysfunction in juvenile salmon (Arkoosh and Collier 2002, Bravo et al. 2008) and cause alterations in growth and metabolism that could increase the risk of mortality (Meador et al. 2006 and 2008). Figure 3-6 shows concentrations of PAHs in the stomach contents of subyearling fall Chinook in various locations of the Columbia River estuary, other Pacific Northwest sites, and hatcheries.

One study detected numerous currently used pesticides present in water quality samples from sites throughout the estuary, with the most frequently detected pesticides being the suspected hormone disruptors atrazine, simazine, and metolachlor (Lower Columbia River Estuary Partnership 2007). Exposure to individual pesticides has sublethal effects on salmon behavior, interfering with predator avoidance, altering homing and migration, and reducing egg fertilization. Health effects include reduced olfactory function, impaired growth, and immune suppression. Pesticides also can be toxic to salmon prey.

Although the concentrations of the individual pesticides detected in the study were lower than threshold levels for health effects in juvenile salmonids, pesticides often were found in combination (Lower Columbia River Estuary Partnership 2007). This is of concern because some pesticides are known to have additive effects. For example, when common pesticides such as diazinon, chlorpyrifos, and carbaryl occur together, even if each is at a relatively low concentration, their combined concentration can have toxic effects on fish and wildlife (Scholz et al. 2006 as cited in Lower Columbia River Estuary Partnership 2007). Among salmonids, carbamate and organophosphate pesticides can have additive effects on olfactory function (Scholz et al. 2006 as cited in Lower Columbia River Estuary Partnership 2007). Some studies suggest that synergistic effects may also be occurring when current-use pesticides occur together in the environment (Anderson and Zhu 2004 and Denton et al. 2003 as cited in Lower Columbia River Estuary Partnership 2007). This is a reminder that the effects of toxic contaminants in the estuary may not be directly proportional to measured concentrations.

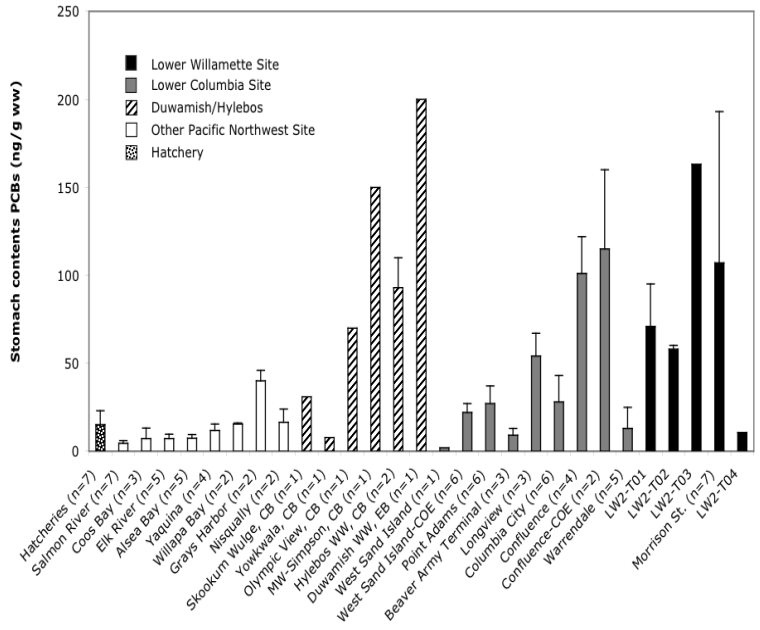


**FIGURE 3-4**
Concentrations of PCBs in the Stomach Contents of Subyearling Fall Chinook
(From Johnson et al. 2007a and 2007b, Lower Columbia River Estuary Partnership, Olson et al. 2008, Stehr et al. 2000, and Lower Willamette Group 2007)

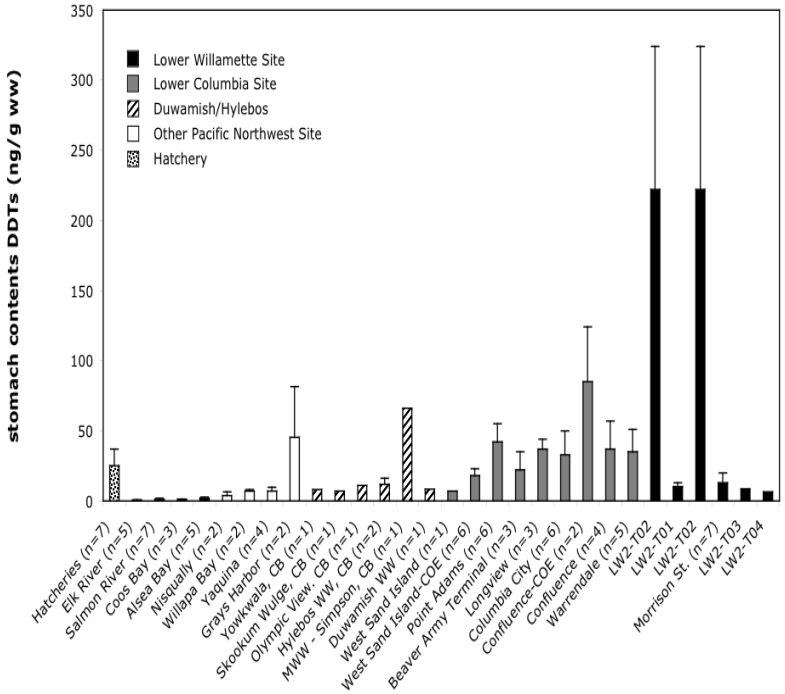


**FIGURE 3-5**
Concentrations of DDTs in the Stomach Contents of Subyearling Fall Chinook
(From Johnson et al. 2007a and 2007b, Lower Columbia River Estuary Partnership, Olson et al. 2008, Stehr et al. 2000, and Lower Willamette Group 2007)

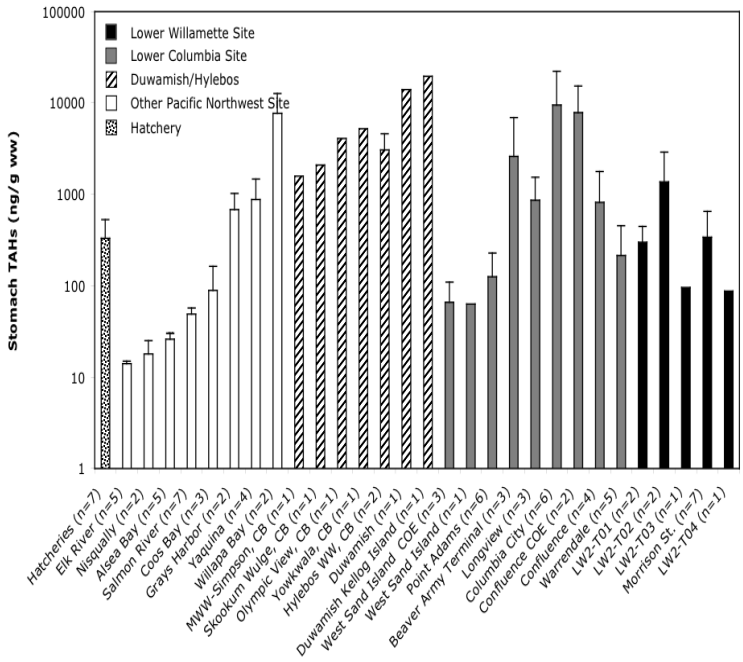


**FIGURE 3-6**
Concentrations of Total Aromatic Hydrocarbons (PAHs) in the Stomach Contents of Subyearling Fall Chinook

(From Johnson et al. 2007a and 2007b, Lower Columbia River Estuary Partnership, Olson et al. 2008, Stehr et al. 2000, and Lower Willamette Group 2007)

# Habitat Opportunity, Habitat Quality, and Synergistic Effects

A lack of habitat opportunity and reduced habitat quality both play a role in limiting the viability of salmon and steelhead in the Columbia River estuary. In terms of habitat opportunity, changes in the timing and volume of Columbia River flows, combined with higher bankfull elevations, have reduced the amount and accessibility of in-channel, off-channel, and plume habitat. Overbank flooding that normally would aid juveniles in accessing off-channel refugia and food resources has been virtually eliminated, and sediment transport processes that structure habitat have been impaired.

Meanwhile, the quality of the habitat available to salmon and steelhead in the estuary has been compromised. Water temperatures are relatively high for cold-water species such as salmon and steelhead and are expected to continue to climb. Researchers have found a variety of toxic contaminants in water, sediments, and salmon tissue in the estuary. With changes in vegetation and flow, juvenile salmonids' traditional macrodetrital food sources have become scarcer and the food base has switched to a microdetritus-based source, thus altering the productivity of the estuary. Predation by northern pikeminnow, pinnipeds, Caspian terns, and cormorants has increased, and it is likely that the presence of native and exotic fish, introduced invertebrates, and invasive plant species is further altering food web dynamics. These and other changes in habitat quality make the estuary a very different place for salmon and steelhead than it was historically.

Habitat quality often is influenced by features that this analysis considers aspects of habitat opportunity, such as river flow and sediment processes. As one example, alterations in flow

have eliminated much of the vegetated wetlands that ordinarily would supply insect prey for juvenile salmonids and macrodetrital inputs to the estuarine food web. In some cases it may not be not be possible to improve habitat quality without reducing limiting factors related to habitat opportunity. Likewise, it may be necessary to address habitat quality issues, such as toxic contaminants, before increasing access to habitat that could be contaminated.

This type of interplay between habitat opportunity and habitat quality is a reminder of how connected limiting factors in the estuary are, even though this chapter describes them discretely. It is possible that some of the limiting factors have synergistic effects, in which the cumulative negative impact of two or more limiting factors is greater than the sum of the impacts of the individual limiting factors. This likely is the case with flow reductions and increases in bankfull elevation, which combine to limit juveniles' access to off-channel habitats. Although synergistic effects are difficult to identify and quantify, the estuary recovery plan module assumes that they exist and that they can be taken advantage of to enhance the beneficial impacts of management actions in the estuary. Chapter 7 addresses the implications of potential synergistic effects more directly.

# Prioritization of Limiting Factors

This estuary recovery module uses a 1-to-5 rating system to prioritize limiting factors by ocean- and stream-type salmon and steelhead, at the estuary scale. PC Trask & Associates, Inc., performed an initial prioritization, based on a synthesis of the three main literature sources (Bottom et al. 2005, Fresh et al. 2005, and Northwest Power and Conservation Council 2004), supplemented by additional literature. (See the discussion of each limiting factors for specific source material.) Staff from the Lower Columbia River Estuary Partnership, NMFS Northwest Fisheries Science Center, NMFS Northwest Regional Office, and Lower Columbia Fish Recovery Board reviewed and provided input on the prioritization.

All three of the main literature sources used in this estuary recovery module identify flow, sediment, water quality, and food web alterations as limiting factors. *Salmon at River's End* (Bottom et al. 2005) analyzes each of the limiting factor categories in the context of habitat opportunity and capacity and how the limiting factor fits within the member/vagrant conceptual framework. The Fresh technical memorandum evaluates selected limiting factors (tern predation, toxics, habitat, and flow) for their impacts on ocean- and stream-type ESUs (Fresh et al. 2005). Finally, the "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan" and its supplement (Northwest Power and Conservation Council 2004) evaluate limiting factors for their impacts to salmonids and the level of certainty that the factor is limiting. Of the limiting factors identified in this module, the only one not identified in at least one of the three main documents is stranding, which the author researched at the suggestion of Washington Department of Fish and Wildlife staff.

In prioritizing limiting factors, the author considered the following: (1) how the three main literature sources evaluated and/or prioritized limiting factors, (2) the magnitude or severity of limiting factors as described in the source documents, (3) estimates of mortality caused by a limiting factor, which were available only for predation-related limiting factors, and (4) the frequency with which a limiting factor was identified in the source documents.

Limiting factors were prioritized individually, without trying to account for potential negative synergistic effects, which are difficult to evaluate.

Table 3-1 shows the results of the limiting factor rating process. Each limiting factor received two scores—one for ocean-type salmonids and one for stream-type salmonids. One simplifying assumption in scoring is that both ocean- and stream-type salmonids express a diversity of life history strategies within ESUs and their constituent populations. Relative scores between ocean- and stream-type salmonids generally reflect the dominant life history stage by providing extra weight to the dominant life history strategy; however, less dominant strategies are considered. For example, reduced off-channel habitat is primarily a limiting factor for ocean-type juveniles because the dominant life history strategy is subyearlings that use shallow-water habitats extensively to feed and rear. However, some ocean-type populations and subpopulations also express a yearling strategy as part of the overall genetic makeup of the population. As a result, both ocean- and stream-type salmonids received scores (albeit lower) for other less dominant life history strategies. The far right-hand column of the table is the total score, which adds ocean- and stream-type impact scores into a single composite score. The assumption that within healthy ESUs there is expression of less-dominant life history strategies is central to *Salmon at River's End* (Bottom et al. 2005) and the Fresh technical memorandum.

Table 3-2 organizes limiting factors into groups based on total score. Top-priority limiting factors are those that have the greatest impact on both ocean- and stream-type ESUs, while lowest priority limiting factors have the least combined impact to ocean- and stream-type ESUs. An important assumption in the rating system is that all limiting factors had an effect on one or both ESU types.

The prioritization of limiting factors in this module should be considered a working hypothesis to be tested and refined through research and evaluation (including a formal expert opinion, or "Delphi," process). Future planning efforts would also be enhanced by a limiting factors analysis at the reach or sub-reach scale, although information is generally not available at this time to consistently identify limiting factors at these finer scales. (In Chapter 5, priority reaches are identified for the 23 management actions.)

# Summary

The identification of limiting factors in the Columbia River estuary is well supported in a variety of literature sources, although additional research is needed to understand the relative impacts of the limiting factors and their interactions. Source documents take different approaches to lumping limiting factors together or splitting them apart for the purposes of evaluation, but all of the documents generally agree that channel confinement and alterations to flows and sediment have significantly degraded the estuary ecosystem in far-reaching ways. Water quality and food web limiting factors also are well documented.

The interconnectedness of these limiting factors suggests the use of ecosystem-based analysis to understand more exactly their effects on salmonids; however, at this point modeling efforts cannot fully explain the complex relationships among limiting factors.

The next chapter examines human actions and natural events that cause or contribute to the limiting factors described in Chapter 3.

**TABLE 3-1**
Impact of Limiting Factors on Ocean- and Stream-Type Salmonids

| Limiting Factor | Level of Impact | | |
|---|---|---|---|
| | Ocean Type* | Stream Type* | Total Score |
| **Habitat-Related Limiting Factors** | | | |
| Reduced in-channel habitat opportunity | | | |
| Flow-related estuary habitat changes | 5 | 3 | 8 |
| Sediment/nutrient-related estuary habitat changes | 4 | 3 | 7 |
| Reduced off-channel habitat opportunity | | | |
| Flow-related changes in access to off-channel habitat | 5 | 3 | 8 |
| Bankfull elevation changes | 5 | 2 | 7 |
| Reduced plume habitat opportunity | | | |
| Flow-related plume changes | 3 | 5 | 8 |
| Sediment/nutrient-related plume changes | 2 | 3 | 5 |
| Water temperature | 5 | 3 | 8 |
| Stranding | 3 | 2 | 5 |
| **Food Web-Related Limiting Factors** | | | |
| Food Source Changes | | | |
| Reduced macrodetrital inputs | 5 | 3 | 8 |
| Increased microdetrital inputs | 3 | 2 | 5 |
| Competition and Predation | | | |
| Native fish | 3 | 3 | 6 |
| Native birds | 2 | 5 | 7 |
| Native pinnipeds | 2 | 5 | 7 |
| Exotic fish | 2 | 2 | 4 |
| Introduced invertebrates | 2 | 2 | 4 |
| Exotic plants | 2 | 2 | 4 |
| **Toxic Contaminants** | | | |
| Bioaccumulation toxicity | 4 | 2 | 6 |
| Non-bioaccumulative toxicity | 4 | 3 | 7 |

*Significance of limiting factor to life history strategy:
1 = No likely effects.
2 = Minor effects on populations.
3 = Moderate effects on populations.
4 = Significant effects on populations.
5 = Major effects on populations.

**TABLE 3-2**
Limiting Factor Prioritization

| Limiting Factor | Limiting Factor Score[a] | Limiting Factor Priority[b] |
|---|---|---|
| Flow-related estuary habitat changes | 8 | Top |
| Flow-related changes in access to off-channel habitat | 8 | |
| Flow-related plume changes | 8 | |
| Water temperature | 8 | |
| Reduced macrodetrital inputs | 8 | |
| Sediment/nutrient-related estuary habitat changes | 7 | High |
| Bankfull elevation changes | 7 | |
| Native birds | 7 | |
| Native pinnipeds | 7 | |
| Non-bioaccumulative toxicity | 7 | |
| Native fish | 6 | Medium |
| Bioaccumulation toxicity | 6 | |
| Sediment/nutrient-related plume changes | 5 | Low |
| Stranding | 5 | |
| Increased microdetrital inputs | 5 | |
| Exotic fish | 4 | Lowest |
| Introduced invertebrates | 4 | |
| Exotic plants | 4 | |

[a]From Table 3-1.
[b]Limiting factors have been prioritized in groups, rather than individually, to avoid a false sense of precision in this qualitative analysis.

CHAPTER 4

# Threats to Salmonids

Chapter 4 identifies and prioritizes threats to ESUs in the Columbia River basin. Threats are the human actions or natural events, such as volcanic eruptions or floodplain development, that cause or contribute to limiting factors (Gaar 2005). Threats may be caused by past, present, or future actions or events.

PC Trask & Associates, Inc., identified and prioritized threats using the same process and sources used to identify and prioritize limiting factors—that is, a thorough review and synthesis of pertinent literature (particularly Bottom et al. 2005, Fresh et al. 2005, and Northwest Power and Conservation Council 2004), supplemented with input from staff at the NMFS Northwest Fisheries Science Center and Northwest Regional Office, Lower Columbia River Estuary Partnership, and Lower Columbia Fish Recovery Board. The module's three key source documents and a number of other sources document both limiting factors and threats. In most cases the literature addresses limiting factors and threats together, and it required substantial effort to separate them for the purposes of this estuary recovery plan module.

The one threat presented in this chapter that the three main source documents do not mention is ship wakes, which can cause stranding of juvenile salmonids. Although the topic of stranding was first raised in a 1977 report (Bauersfeld 1977), the extent of stranding remains unclear. Washington Department of Fish & Wildlife staff suggested that the topic be addressed in this recovery plan module.

The relationship between limiting factors and threats is not necessarily one-to-one. A single threat can contribute to several limiting factors, and in many cases a limiting factor exists because of the effects of multiple and varied threats. (Table 4-1, which is presented later in this chapter, shows the linkages between the limiting factors in Chapter 3 and the threats described in Chapter 4.) For ease of understanding, this chapter organizes threats to salmonids into the following groupings: flow, sediment, structures such as dikes and jetties, ship wakes, food web (including species relationships), and water quality in the estuary. The presentation of threats as discrete activities or phenomena is an oversimplification of complex physical and biological relationships that affect salmon survival. The threats related to flow, sediment transport, and food webs are particularly difficult to tease apart and discuss discretely. Thus the reader should bear in mind that describing threats individually does not fully capture the dynamic interplay of forces that are currently putting salmonids in the estuary at risk. The complexity of these forces is illustrated in Figure 4-1, which is a representation of a conceptual model of the Columbia River estuary developed by the U.S. Army Corps of Engineers (Diefenderfer et al. 2005). The model provides in-depth detail on the relationships between limiting factors and threats.

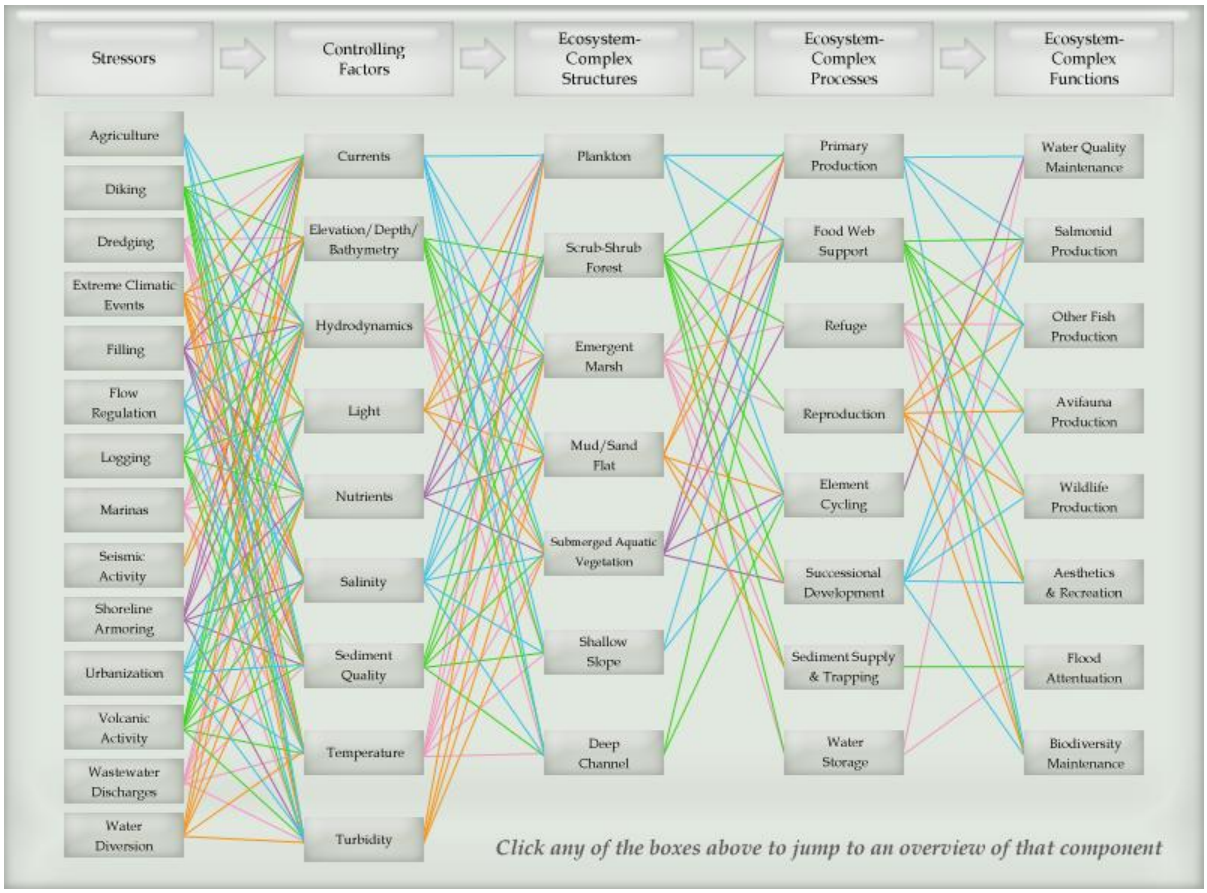


**FIGURE 4-1**
Conceptual Model of the Columbia River Estuary
*(Note: "Stressors" are equivalent to threats as defined in this module.)*
*(Figure provided courtesy of the U.S. Army Corps of Engineers.)*

Most of the human threats described in this chapter are the result of the cumulative impacts of European Americans living in the Northwest. From an ecological perspective these impacts have taken place relatively quickly. Consider that in 1770, when American Robert Gray first crossed the Columbia River bar, about 100,000 Native Americans lived in the Columbia River basin (Oregon State University 1998). Today the population of the Columbia Basin is approximately 5 million (National Research Council 2004). In the early years of Euro-American settlement, the area's abundant natural resources supported farming, mining, logging, fishing, and other activities that modified the landscape into productive uses for people. Later, the availability of cheap hydroelectric power helped fuel expanded agriculture, manufacturing, and development and the rise of urban centers such as Portland. The impacts of these activities on salmonids in the estuary have been substantial.

# Flow-Related Threats

Over the last 4,000 years, salmon thrived in the Columbia River by adapting to habitats created by characteristics of the land and water flow (Fresh et al. 2005). Key attributes of flow include magnitude and timing, both of which have changed significantly in the

Columbia River over the last two centuries. Today the mean flow to the estuary is about 16 percent less than it was in the latter part of the nineteenth century (Jay and Kukulka 2003), and spring freshet peak flows have declined about 44 percent in that same time period (Jay and Kukulka 2003). In addition, the timing of peak flows occurs about 14 to 30 days earlier than it did historically (Jay and Kukulka 2003). Reductions in the spring freshet flows are shown in Figure 4-2, which presents simulated mean monthly discharge at Bonneville Dam before development of the hydrosystem and under current hydrosystem configurations and operations.

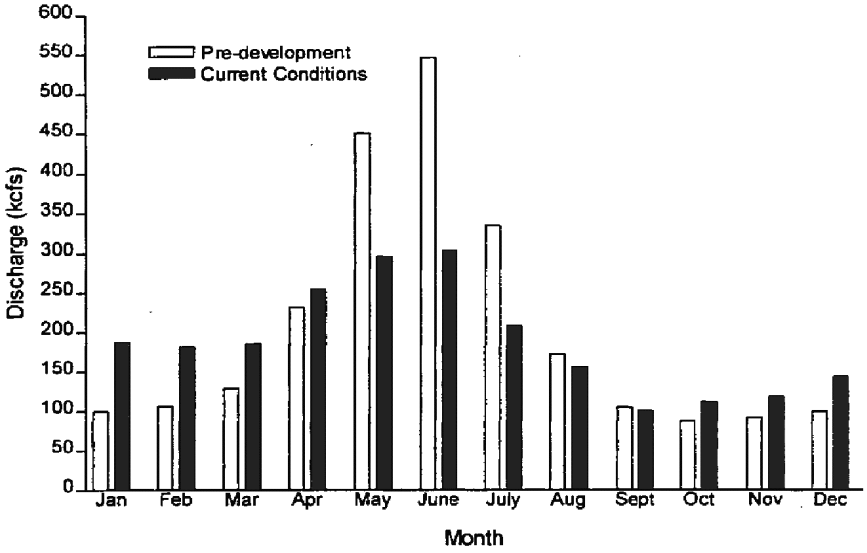


**FIGURE 4-2**
Changes in the Annual Columbia River Flow
(Adapted from National Marine Fisheries Service 2000.)

Flow alterations, in connection with other factors, can increase or decrease salmonids' ability to access habitats and the capacity of habitats to sustain salmonids (Bottom et al. 2005). In the case of the Columbia River, alterations in the timing, magnitude, and duration of flows are responsible for dramatic changes in habitat opportunity and capacity in the estuary, including effects on groundwater recharge, cold-water upwelling, flooding, off-channel habitat quality and quantity, and water quality. Climate fluctuations, the withdrawal of water, and regulation of river flow have altered the amount and timing of instream flows entering the estuary and plume.

***Affected salmonids:*** Alterations in the magnitude and timing of Columbia River flows affect both ocean- and stream-type juvenile salmonids. Ocean-type juveniles spend more time in the estuary, where they rely on shallow vegetated marsh habitats and upland swamp habitats (Northwest Power and Conservation Council 2004). Chum salmon (ocean-type) also spawn in the mainstem and are affected by low flows during the spawning and egg incubation life stages. In extreme cases, redds may have been dewatered; however, a minimum flow now has been administratively set from November through April to reduce the potential for dewatering of chum redds located immediately below Bonneville Dam. Ocean-type salmonids also rely on seasonal overbank flows to access habitats and preferred food sources.

Stream-type juveniles do not spend much time in the estuary, but research indicates that they may use the Columbia River plume habitat as they adjust to saltwater conditions (Fresh et al. 2005). Columbia River flows have a direct effect on the plume's surface area, volume, frontal features, and extent offshore (Fresh et al. 2005). Flow alterations also affect sediment transport processes and water quality.

## Threat: Climate Cycles and Global Climate Change

Natural variations in Columbia River flow as a result of long- and short-term climate fluctuations have occurred throughout history. The Pacific Decadal Oscillation (PDO) alternates between cold and warm phases approximately every 30 years (Fresh et al. 2005). The cold, rainy phase is typical of the Northwest and increases flows, while the warm phase is drier and decreases flows (Fresh et al. 2005). The El Niño/Southern Oscillation (ENSO) is a shorter, 3- to 7-year phenomenon that similarly has cold and warm phases that may magnify or reduce the effects of the PDO.

Climatic fluctuations have a significant effect on the amount and timing of water flowing to the estuary (Fresh et al. 2005). Since 1878, climatic changes have reduced Columbia River flows by 9 percent (Jay and Kukulka 2003). The NMFS Northwest Fisheries Science Center has observed changes in PDO and ENSO indicators that suggest that changes in ecosystem structure can be expected that are unfavorable for salmon and steelhead (Varanasi 2005). These changes may continue over the next several years.

Scientists believe that the release of high levels of carbon dioxide as a result of human activities is contributing to global climate change. The source of these releases includes the use of fossil fuels to run cars, heat homes and offices, and power factories. Over the past century, global climate change has caused sea levels to rise about 4 to 5 inches (10 to 13 centimeters), worldwide precipitation to increase by about 1 percent, and the frequency of extreme rainfall events to increase in much of the United States (U.S. Environmental Protection Agency 2005). Sea level rise is predicted to accelerate worldwide in the coming decades as a result of global climate change (Intergovernmental Panel on Climate Change 2007). The Intergovernmental Panel on Climate Change has observed that sea levels rose at an average rate of 1.8 millimeters per year from 1961 to 2003 and may be 0.18 to 0.59 meter (0.6 to 1.9 feet) higher at the end of the 21st century than they were during the baseline period of 1980 to 1999 (Intergovernmental Panel on Climate Change 2007).

The Independent Scientific Advisory Board for the Northwest Power and Conservation Council (2007) reports that the Pacific Northwest has warmed about 1° C (1.8° F) since 1900 (this is about 50 percent more than the global average for the same time period) and is projected to warm at a rate of 0.1 to 0.6° C (0.18 to 1.1° F) per decade during the next century. Over the long term, winter precipitation is expected to increase, and summer precipitation is expected to decrease. Within the Columbia River basin, expected effects of rising temperatures include more precipitation falling as rain rather than snow, diminished snow pack, associated reductions in late-summer/early-fall flow, altered timing of flows, increased peak flows, and continued rises in water temperatures. In the estuary, these factors could lead to changes in flooding and ecosystem processes and conditions that already are considered limiting factors for salmon and steelhead—namely, flow-related habitat changes, sediment transport, food web dynamics, populations of non-native species, and water temperature (Independent Scientific Advisory Board 2007). Increasingly, water

temperatures in the estuary are approaching the upper thermal limit for salmonids that use the estuary during summer months (National Research Council 2004). Further increases in water temperature could render some current estuarine habitat unsuitable for salmonids, enhance conditions for warm-water fish that prey on or compete with juvenile salmonids, and alter physiological processes such as growth and metabolism among juveniles (Independent Scientific Advisory Board 2007). Some evidence suggests that salmonid response to climate change varies among populations (Crozier and Zabel 2006 as cited in Independent Scientific Advisory Board 2007). Other potential impacts of global climate change in the estuary may include continued rises in sea level and associated effects on intertidal habitat formation and maintenance.

Study of the impacts of global climate change is an evolving field, and additional research is needed to understand the phenomenon's likely effects on estuarine habitats and processes with specificity. Although the estuary recovery plan module does not consider global climate change separately from other climate-related impacts in the estuary, the topic should receive increasing attention for its potential to affect fish management in the Columbia River basin as a whole. As additional scientific information on global climate change becomes available, it will be incorporated into any updates of the estuary recovery plan module and implementation of associated management actions.

***Limiting factors this threat contributes to***: Flow-related estuary habitat and plume changes, flow-related changes in access to off-channel habitat, water temperature, and reduced macrodetrital inputs.

## Threat: Water Withdrawal

Reduction in the amount of instream flow in a river system is an important measure of alterations to the system (Fresh et al. 2005). Water withdrawals affect both the magnitude and timing of flows entering the estuary and plume.

Historically, flow conditions in the estuary were determined by seasonal climate effects (such as precipitation) and hydrology. Since the early 1900s and to a larger degree since the 1960s, irrigation practices have reduced flows in the Columbia River. Water withdrawals as a result of agricultural irrigation and other water uses are estimated to have reduced flows of the Columbia River by 7 percent since the latter part of the nineteenth century (Jay and Kukulka 2003).

Other human activities that reduce flows are the result of upstream use of surface water and groundwater for commercial, industrial, municipal, domestic, and other purposes (National Research Council 2004).

Irrigation withdrawals of surface water account for approximately 96 percent of total water used, while municipal and other uses account for only 4 percent (National Research Council 2004). On the other hand, about 75 percent of all groundwater withdrawals support irrigation and the remaining 25 percent are used for other purposes (National Research Council 2004).

***Limiting factors this threat contributes to***: Flow-related estuary habitat and plume changes, flow-related changes in access to off-channel habitat, and reduced macrodetrital inputs.

### Threat: Flow Regulation

The timing and magnitude of spring freshets have been drastically altered by management of the Columbia River hydrosystem (Fresh et al. 2005). Jay and Kukulka (2003) estimate that 26 percent of the overall reduction of freshet season flow since the late nineteenth century is attributable to flow regulation. Together with irrigation storage and withdrawal, flow regulation has increased fall and winter flows (winter flows have increased because of pre-release before the freshet season), and much of the seasonal timing of flows in the estuary can be attributed to flood control and hydroelectric operations.

Flow regulation is a function of the hydrosystem in the United States and Canada. The first hydroelectric facility in the lower Columbia Basin—the T.W. Sullivan Dam in Oregon City—was constructed in 1888. Since then, more than 450 dams have been built in the Columbia River basin (Columbia Basin Trust). These dams supply British Columbia with 50 percent of its electricity, while the American Northwest relies on hydropower for about two-thirds of its electricity (Columbia Basin Trust). Columbia River dams also provide flood control, enhance irrigation, and improve navigation.

The total active storage of water in the Columbia River Basin is 42 million acre-feet (Northwest Power and Conservation Council 2001), with dams in Canada accounting for about half of the total storage (Northwest Power and Conservation Council 2001). Major Canadian dams include the Duncan, Arrow, and Mica dams. Major U.S. hydroelectric facilities with significant storage include the Grand Coulee, Dworshak, Hungry Horse, and Libby dams. In addition, the U.S. Bureau of Reclamation owns and operates dozens of water storage dams in the Snake and Yakima rivers. The U.S. Army Corps of Engineers also operates many large flood control projects in the Willamette River.

Several recent changes in hydrosystem operations have been implemented to benefit salmonids throughout the basin. These include increasing flows by minimizing winter flood control drafts and reducing the amount of water needed to refill projects during the spring—measures that benefit spring juvenile salmonid migration in the mainstem Snake and Columbia rivers. Also, summer flows have been augmented to cool Snake River temperatures and assist migration of Snake River salmon and steelhead. Finally, a minimum flow has been administratively set from November through April to reduce the potential for dewatering of chum redds, primarily in Reach G in the estuary.

***Limiting factors this threat contributes to***: Flow-related estuary habitat and plume changes, flow-related changes in access to off-channel habitat, increased microdetrital inputs, and reduced macrodetrital inputs.

## Sediment-Related Threats

Changes to seasonal flows, dredging, and the entrapment of sediment in reservoirs have altered those habitat-forming processes in the Columbia River estuary and plume that relate to sediment.

As described in Chapter 3, the transport of sediment is fundamental to habitat-forming processes in the estuary. Sediment helps create and maintain and promote wetlands, which are important to carbon cycling in the estuary and provide habitat for juvenile salmonids. Sediment also provides important minerals and nutrients that support food production in

the estuary and plume. And suspended sediments contribute to turbidity, which is important to salmonids because of the protection it provides from predators. Although the effects of impaired sediment processes on salmonids in the estuary are not fully understood, the magnitude of change and the key role that sediments play in habitat- and food-related processes are significant.

Entrapment of sediment in reservoirs, reduced downstream transport of sediment as a result of altered spring freshets, and dredging are the primary sediment-related threats to salmonids in the estuary. Ocean-type juvenile salmonids are affected by sediment-related changes in habitat in the estuary and by reduced turbidity (which can increase predation). Stream-type juveniles are affected by reduced turbidity in deeper waters in the estuary and plume.

## Threat: Entrapment of Fine Sediment in Reservoirs

Reduction in water velocity as a result of upstream reservoirs has altered the transport of organic matter associated with fine sediments such as silt and clay. Fine sediments entering the estuary originate in the upper watersheds of the Snake River (Northwest Power and Conservation Council 2004). Reduced velocities behind upstream reservoirs cause reservoirs to act as a sink to fine sediments and likely reduce amounts delivered to the estuary (Northwest Power and Conservation Council 2004). Currently, organic matter associated with fine sediments supplies the majority of estuarine secondary productivity in the food web (Simenstad et al. 1984 as cited in Northwest Power and Conservation Council 2004). Additionally, reductions in the quantity of fine sediments can increase water clarity and thus contribute to increased predation by piscivorous fish and birds.

***Limiting factors this threat contributes to***: Flow-related plume changes, sediment/nutrient-related estuary habitat changes, native birds, native fish, and exotic fish.

## Threat: Impaired Transport of Coarse Sediment

Historically, the force of spring freshets moved sand down the river and into the estuary, where it formed shallow-water habitats that are vital for salmonids, particularly ocean types. Today, alterations to spring freshet flows have reduced sand discharge in the Columbia River estuary to 70 percent of nineteenth-century levels (Jay and Kukulka 2003). It is likely that the magnitude of change in sand transport affects habitat-forming processes and reduces turbidity, which results in increased predation in the estuary and plume environments.

***Limiting factors this threat contributes to***: Flow-related plume changes and sediment/nutrient-related estuary habitat changes.

## Threat: Dredging

Dredging and the disposal of sand have been a major cause of estuarine habitat loss over the last century (Northwest Power and Conservation Council 2004). Currently, three times more sand is dredged from the estuary than is replenished by upstream sources (Northwest Power and Conservation Council 2004). In addition to causing habitat loss, dredging may have impaired sediment circulation in nearshore ocean areas and resulted in impacts to benthic organisms through disturbance. Still other impacts include the entrainment of crab, juvenile salmonids, sturgeon, and other fish and wildlife species.

Additional losses of vegetated wetlands in the Columbia River estuary are attributable to filling activities, with deposition of dredged materials accounting for most of the filling activities in the estuary (Fresh et al. 2005). Most dredged materials result from maintenance of the shipping channel. Dredged materials are disposed of in-water, along shorelines, or on upland sites; some dredged material disposal sites are shown in the reach maps in Appendix A. Annual maintenance dredging since 1976 has averaged 3.5 million cubic yards per year (Northwest Power and Conservation Council 2004). Significantly more dredged material has resulted from the U.S. Army Corps of Engineers' 43-foot channel deepening project. Dredge fill and diking activities have significantly reduced the availability of wetlands to the river, while placement of dredged material in several areas has increased nesting habitat for Caspian terns and cormorants.

***Limiting factors this threat contributes to***: Sediment/nutrient-related estuary habitat and plume changes and native birds.

# Structural Threats

The development of instream and over-water structures has altered circulation patterns, sediment deposition, sediment erosion, and the formation of habitats in the estuary. Examples of instream and over-water structures include jetties, pile dikes, tide gates, docks, breakwaters, bulkheads, revetments, seawalls, groins, and ramps (Williams and Thom 2001). Such structures create favorable conditions for predators such as northern pikeminnow and walleye, and they can reduce circulation in areas outside of the channel. Instream and over-water structures are found in all reaches of the estuary (for locations, see the reach maps presented in Appendix A).

Another structural threat is reservoirs associated with the hundreds of dams in the Columbia River basin. The construction and operation of these reservoirs has contributed to changes in the temperature of water entering the estuary.

***Affected salmonids:*** Structural threats primarily affect ocean-type juvenile salmonids because of their longer residency time in the estuary and their wider use of off-channel habitats; however, scientists are now hypothesizing that stream-type juveniles forage outside of deeper channels in shallow-water habitats, where they may fall victim to predators that congregate near instream and over-water structures.

## Threat: Pilings and Pile Dike Structures

Construction of the North and South jetties has altered sediment accretion and erosion processes near the mouth of the Columbia River. Sediment accretion in the marine littoral areas adjacent to the mouth has decreased the inflow of marine sediments into the estuary (Northwest Power and Conservation Council 2004), while the extensive use of pilings, pile dikes, and other structures to maintain the shipping channel has affected natural flow and sedimentation patterns. Pile dikes maintain the navigation channel by reducing the cross section of the river, increasing the velocity of the river within the channel, and at times slowing velocities immediately downstream of the dike. Development of the navigation channel has reduced flow to side channels and peripheral bays (Northwest Power and Conservation Council 2004). In addition, pile dikes and similar structures may create

conditions that increase predation on juvenile salmonids by northern pikeminnow and other piscivorous fish.

***Limiting factors this threat contributes to***: Sediment/nutrient-related estuary habitat and plume changes and exotic fish.

## Threat: Dikes and Filling

Dikes and filling activities have significantly altered the size and function of the Columbia River estuary. Since the early 1900s, dikes have been built to allow agricultural and residential uses (Fresh et al. 2005). Dikes are thought to have caused more habitat conversion in the estuary than any other human or natural factor (Thomas 1983, as reported in Northwest Power and Conservation Council 2004). The effects of diking on estuarine habitats are directly proportional to elevation, with the greatest impacts on the highest elevation estuarine habitats: forested wetlands, followed by tidal swamps and tidal wetlands. Diking-related impacts to these habitats have reduced their availability to juvenile salmon and steelhead (Thomas 1983, as reported in Northwest Power and Conservation Council 2004). Figure 4-3 shows the various zones found in typical estuaries. The emergent vegetation, diked marsh, shrub wetlands, and forested wetlands are the zones most affected by dike and filling practices (reprinted from Thom 2001). Diked areas and the historical floodplain in the Columbia River estuary are shown in the reach maps presented in Appendix A.

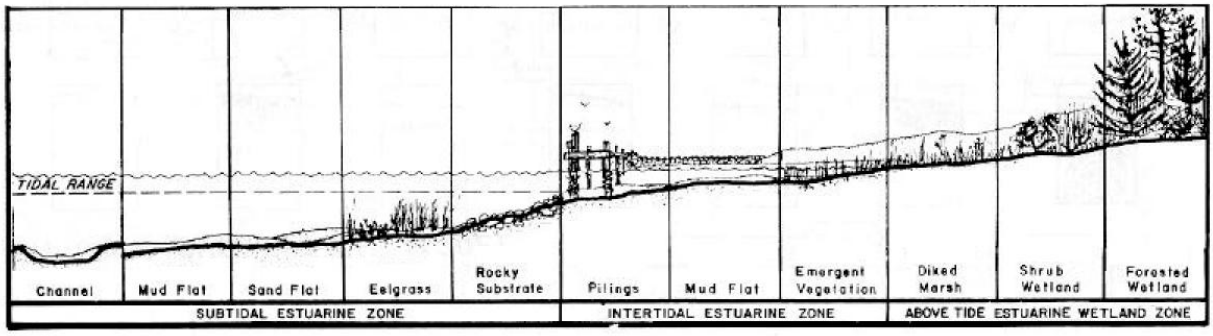


**FIGURE 4-3**
Subtidal, Intertidal, and Above-Tidal Estuarine Wetland Zones

Before development of the Columbia River hydrosystem and diking and filling, the estuary was dominated by macrodetrital inputs that originated from vegetated wetlands within the estuary. As a result of diking and filling practices and flow alterations (such as changes in the number and timing of spring freshets), emergent plant production in the estuary has decreased by 82 percent and macroalgae production has decreased by 15 percent (Northwest Power and Conservation Council 2004). The availability of insect prey for ocean-type salmonids has been reduced as vegetation has been removed via diking and filling activities and associated dike vegetation maintenance.

***Limiting factors this threat contributes to***: Reduced macrodetrital inputs, sediment/nutrient-related estuary habitat and plume changes, bankfull elevation increases, and exotic plants.

### Threat: Reservoir-Related Temperature Changes

More than 450 dams have been built in the Columbia River basin (Columbia Basin Trust). The associated impoundment of water in upstream reservoirs increases the surface area of the Columbia River, allowing more solar heating of river water than occurs in free-flowing river stretches. This solar heating, combined with the reduced flows from upstream impoundments, has contributed to increased water temperatures in the Columbia River. Measurements at Bonneville Dam indicate that periods of increased temperatures are lasting longer than they did historically (National Research Council 2004). Currently, during summer months, average and maximum values of Columbia River water temperatures are often above 20° C (68°F), which approaches the upper limits of thermal tolerance for cold-water fishes such as salmon (National Research Council 2004). (For additional information on increases in water temperature in the lower Columbia River, see Figure 3-2 and the text that precedes the figure.)

The dynamics of reservoir-related temperature changes in the estuary are complicated and are affected by factors such as thermal inertia, which, among other things, contributes to delayed fall cooling and spring warming of downstream waters. Additional study is needed to better understand reservoir-related temperature changes and their effects on salmonids rearing in the estuary.

***Limiting factors this threat contributes to***: Water temperature.

### Threat: Over-Water Structures

Over-water structures refer to docks, piers, transient moorage, log rafts, and other structures. These structures block sunlight, reduce flow, and trap sediments downstream of pilings (Kahler, Grassley, and Beauchamp 2000; Nightingale and Simenstad 2001). They also change circulation patterns and reduce edge habitats for ocean-type salmonids. Over-water structures contribute to predation on salmonids by altering habitat, creating microhabitats and favorable conditions for predators, especially the northern pikeminnow and non-native species such as small-mouth bass (Kahler, Grassley, and Beauchamp 2000; Nightingale and Simenstad 2001).

Although the actual square footage of over-water structures in the Columbia River estuary has never been inventoried, the structures themselves number in the thousands. Some research has occurred on the effects of breakwaters and over-water structures in the context of marinas. Salmon fry tend to concentrate in higher densities around these structures, thus increasing the risk of predation (Williams and Thom 2001).

***Limiting factors this threat contributes to***: Sediment/nutrient-related estuary habitat changes, and exotic fish.

## Food Web-Related Threats

As described in Chapter 3, changes in the estuarine food web can ripple through the ecosystem, altering energy pathways, feeding patterns, predator/prey relationships, and competition within and among species. As a result of increased nutrients, elevated water temperatures, slower passage of water through reservoirs, and entrapment of organic matter in reservoirs, concentrations of phytoplankton at the base of the food web in the

estuary are higher than they were historically. The introduction of exotic species such as shad may have accelerated the pace of ecological change in the estuary by permanently altering food webs. Food webs also have been altered by sediment transport, in that microdetrital food particles adhere to sediment suspended in the water column, making different food sources available to different species than was the case historically.

***Affected salmonids:*** Both stream- and ocean-type salmonids are affected by energy-related threats—stream types primarily through increased predation in deep-water habitats and ocean types primarily through food web changes in the estuary. Ocean-type juveniles also are affected by reduced availability of insect prey as a result of the construction and maintenance of dikes.

## Threat: Increased Phytoplankton Production

A reduction in macrodetrital inputs has shifted the food base in the estuary to phytoplankton produced in and imported from upstream reservoirs (Northwest Power and Conservation Council 2004), or produced as a result of augmented levels of nutrients from urban, industrial, and agricultural development. Phytoplankton support a food web that is less accessible to ocean-type salmonids occupying shallow edge habitats than the historical food web (Northwest Power and Conservation Council 2004). A shift from a generally animal-based salmonid diet to a generally plant-based diet may impair caloric inputs (Garman 1991; Cloe and Garman 1996; Nakano, Miyasaka, and Kuhara, 1999; Henschel, Mahsberg, and Stumpf 2001), and thus the fitness of salmonids that rely on estuarine rearing habitats to grow and prepare for ocean migration. The shift in food sources from a macrodetrital base to a microdetrital base provides different food sources than salmonids historically were accustomed to, in different places within the estuary, and this may favor different species. Because this area of study is immature in the estuary, it is difficult to establish which species benefit more than others.

***Limiting factors this threat contributes to***: Increased microdetrital inputs.

## Threat: Altered Predator/Prey Relationships

Although predation has always occurred in the estuary ecosystem, the cumulative effect of altered flows, changes in sediment transport processes and food sources, introduced species, hatcheries, upstream habitat impacts, hydroelectric impacts, and contaminants have recast estuary and plume environments such that predator/prey relationships have changed significantly. As a result, significant numbers of salmon are lost to fish, avian, and marine mammal predators during migration and residency in the estuary (Northwest Power and Conservation Council 2004). Fish predators include northern pikeminnow, walleye, smallmouth bass, and catfish; avian predators include Caspian terns, double-crested cormorants, and gull species; and marine mammal predators include Steller and California sea lions and harbor seals.

Degraded conditions (loss of habitat and altered food web) in the Columbia River estuary and the timing of large hatchery releases have increased the likelihood that mortality from competition may occur under some circumstances (Northwest Power and Conservation Council 2004). Mortality from intra-species competition has been documented in the Skagit River estuary (Beamer et al. 2005), and there is speculation that it may be a factor in the Columbia River as well (Northwest Power and Conservation Council 2004). If inter-species

competition is occurring, it is likely to have the greatest impact on ocean-type salmonids because of their longer residence time in the estuary (Northwest Power and Conservation Council 2004). If density dependence is affecting stream-type juveniles, it likely happens in the plume.

As the result of human alterations of the estuary environment, native species such as Caspian terns and double-crested cormorants have significantly increased in number, with measurable impacts on stream-type salmonids (Bonneville Power Administration, U.S. Bureau of Reclamation, and U.S. Army Corps of Engineers 2004). These increases in population in the Columbia River estuary are attributed to the deposition of dredged materials in the estuary that represent high-quality habitat for the birds (Bottom et al. 2005) and predation opportunities for cormorants created through the placement of pilings, pile dikes, and other structures. The loss of habitat elsewhere has contributed to terns and cormorants effectively relocating to the Columbia River estuary, with the populations there now representing the largest nesting colonies in the world.

Similarly, the new microdetritus-based food web in the estuary has benefited zooplanktivores, including American shad (an introduced species) (Northwest Power and Conservation Council 2004). Although shad do not appear to be in direct competition with salmonids, their biomass alone—more than 4 million returning adults a year—represents a threat to trophic relationships in the Columbia River. Future increases in water temperatures as a result of climate change may improve conditions for shad in the Columbia River Basin and lead to their continued expansion (Independent Scientific Advisory Board 2008). Other exotic fish species such as introduced walleye and catfish also have been able to capitalize on degraded conditions in the upper reaches of the estuary and altered food web dynamics through predation and competition for food resources (Northwest Power and Conservation Council 2004).

Pinniped predation on adult spring Chinook and winter steelhead continues to increase. On the West Coast the total abundance of California sea lions is approximately 250,000; Stellar sea lions total about 31,000, and Pacific harbor seals total about 25,000 (Griffin 2006). Each spring about 1,000 Stellar sea lions, 3,000 Pacific harbor seals, and 800 California sea lions take up residence in the lower estuary (Griffin 2006). About 1,000 sea lions and harbor seals enter the freshwater portion of the estuary; of these, approximately 80 animals (primarily California sea lions) congregate at Bonneville Dam. The U.S. Army Corps of Engineers' estimates that annual adult mortality at Bonneville Dam because of pinnipeds (primarily California sea lions) ranged from 0.4 percent (2002) to 4.2 percent (2007) during the study period ending in 2010 (U.S. Army Corps of Engineers 2010).[1] Other, radio telemetry-based studies suggest that annual pinniped predation on spring Chinook and winter steelhead at Bonneville Dam may be as high as 8.5 percent and 20 percent, respectively (NMFS 2008b, Appendix G). There is a need for better estimates of the mortality caused by pinnipeds throughout the estuary and plume. Unsubstantiated estimates suggest a mortality rate of 10 percent of the entire adult spring Chinook and steelhead runs in a given year.

Non-native plant species have altered habitat and food webs in the Columbia River estuary. The rate of intentional and unintentional introductions has been increasing over the past 100

[1] Estimated consumption of adult salmonids ranged from a low of 1,010 in 2002 to a high of 6,081 in 2010; the percent of run consumed varied among reporting years in part because of changes in run size.

years, mostly as a result of horticultural practices and the increase in travel and commerce in the Columbia River. Four of those species—purple loosestrife, Eurasian water milfoil, parrot feather, and Brazilian elodea—are of particular concern. Each of these species, in its own way, alters habitat and food webs in the estuary. Purple loosestrife, for example, adapts easily to environmental changes and expands its ranges quickly. The primary ecological effect of purple loosestrife is that it disrupts wetland ecosystems by displacing native plants. Eventually, animals that rely on native flora for food, nesting, or cover also are displaced (Northwest Power and Conservation Council 2004).

***Limiting factors this threat contributes to***: Native birds, native fish, native pinnipeds, introduced invertebrates, exotic fish, and exotic plants.

### Threat: Ship Ballast Practices

Ship ballast practices have been responsible for the introduction of at least 21 exotic species in the Columbia River estuary (Sytsma et al. 2004). When ships release ballast water, non-indigenous species can enter receiving waters. Most of the non-indigenous species in the estuary have originated from Asia (Sytsma et al. 2004). Populations of non-native copepods have established themselves in Reaches A and B (Youngs Bay, Cathlamet Bay, and Grays Bay), and the New Zealand mudsnail has colonized other estuary reaches. The Asian bivalve *Corbicula fluminea* has expanded its range in the estuary, with densities of 10,000 per $m^2$ being recorded in Cathlamet Bay; however, densities of 100 to 3,000 $m^2$ are more common (Northwest Power and Conservation Council 2004). These and other non-indigenous invaders disrupt food webs and out-compete juvenile salmonids' native food sources.

An emerging source of concern regarding ship ballast practices is the potential entrainment of juvenile salmonids when large ships take on ballast water as they leave ports unloaded. This issue is being evaluated in relevant Endangered Species Act (ESA) Section 7 consultations (Tortorici 2008).

***Limiting factors this threat contributes to***: Introduced invertebrates.

## Water Quality-Related Threats

The release of toxic contaminants, nutrient loading, and reduced dissolved oxygen have altered the quality of salmonid habitats in the Columbia River estuary. Currently the estuary receives toxic contaminants or nutrients from more than 100 point sources and numerous non-point sources, such as surface and stormwater runoff from urban and agricultural areas (Fuhrer et al. 1996 as referenced in Fresh et al. 2005). In most areas, nonpoint sources such as agricultural, urban, industrial, and timber harvest practices contribute greater nutrient loads than point sources do (Wise et al. 2007). The Snake, Yakima, Deschutes, and Willamette rivers contribute most of the nutrient loads discharged to the Columbia River. Nutrient yields (loads normalized for basin size) are generally greater in basins west of the Cascade Range and are correlated with precipitation and point-source loads (Wise et al. 2007).

## Threat: Agricultural Practices

The health of an aquatic ecosystem is substantially affected by agricultural, urban, and industrial practices and wastewater discharge (National Research Council 2004). Specific threats include increased nutrients (nitrogen and phosphorus), sediment, and organic and trace metals (National Research Council 2004). For example, Wise et al. (2007) found a significant correlation between total nitrogen yields in basins west of the Cascades and fertilizer and manure loads. Increased nutrient loads from anthropogenic sources can lead to increased phytoplankton concentrations, decreased water clarity, and depressed dissolved oxygen levels, especially in areas with longer residence times and warmer water temperatures. DDT, other banned pesticides that have persisted in the environment, and pesticides in current use are entering the estuary from agricultural runoff, some of which originates outside the lower Columbia River basin. The middle and upper Columbia are primary sources of DDT and other organochlorine pesticides in the estuary, as are tributaries such as the Yakima and Willamette rivers (Clark et al. 1998, Williamson et al. 1998, Hinck et al. 2006, Johnson and Norton 2005, McCarthy and Gale 2001 as cited in Lower Columbia River Estuary Partnership 2007). A 2007 study confirmed the presence of the pesticides atrazine, simazine, metolachlor, EPTC, DCPA, and diuron at sites throughout the estuary, often in combination (Lower Columbia River Estuary Partnership 2007). The timing of detections suggests that precipitation events play an important role in transporting pesticides to the Willamette River, which is a primary contributor of both agricultural and urban/industrial contaminants to the Columbia River estuary.

The U.S. Geological Survey's National Stream Quality Accounting Network (NASQAN) program also reports detection of a wide range of commonly used pesticides at sampling sites near Bonneville Dam and at the confluence of the Willamette and Columbia rivers (Fresh et al. 2005). Detected pesticides include simazine, atrazine, chlorpyrifos, metolachlor, diazinon, and carbaryl. Arsenic and trace metals such as copper, iron, and manganese also have been detected. Although trace metals occur naturally, they also are introduced through human activities, such as the use of lead arsenate as an insecticide for apples (Fresh et al. 2005). Water-soluble contaminants, trace metals, and chlorinated compounds have been detected in the estuary (Fresh et al. 2005), and DDT, PCBs, dioxins, and metals have been detected at elevated levels in tissue from fish in the estuary (Northwest Power and Conservation Council 2004).

***Limiting factors this threat contributes to***: Non-bioaccumulative toxicity, bioaccumulation toxicity, and increased microdetrital inputs.

## Threat: Urban and Industrial Practices

The Columbia River downstream of Bonneville Dam is the most urbanized stretch in the entire basin. The area has more than 100 point sources that are known to discharge directly into the Columbia River estuary; these include chemical plants, pulp and paper mills, hydroelectric facilities, municipal wastewater treatment plants, and seafood processors (Fuhrer et al. 1996 as cited in Lower Columbia River Estuary Partnership 2007). Potential nonpoint sources include hazardous waste sites, landfills, marinas and moorages, and overland surface runoff that transports nutrients, sediment, PAHs, metals, and pesticides from streets, yards, and industries.

The largest sources of effluent in this area are the Portland and Vancouver sewage treatment plants (Fresh et al. 2005), with Portland's wastewater treatment facility being the largest point-source discharger in the Columbia Basin (Wise et al. 2007). The annual nutrient loads from this facility equal approximately 2 to 3 percent of the annual in-stream nutrient loads at the Beaver Army Terminal water quality sampling site, downstream of Longview, Washington (Wise et al 2007). Contaminants also are transported to the estuary from areas above Bonneville Dam, such as the Deschutes, Yakima, and Snake rivers. These rivers, together with the Willamette, contribute most of the nutrient loads discharged to the Columbia River (Wise et al. 2007).

An intensive study of sediments in Portland Harbor (the stretch of the Willamette River from Sauvie Island to Swan Island) has uncovered pesticides, PCBs, and other toxic chemicals. In general, studies have shown that PCB and PAH concentrations in salmon and their prey in the estuary are comparable to those in organisms in other moderately to highly urbanized areas (Fresh et al. 2005, Lower Columbia River Estuary Partnership 2007, Johnson et al. 2007b). Industrial contaminants such as PAHs have been detected in sediments from the lower Willamette River in Portland at levels that exceed state or Federal sediment quality guidelines. The U.S. Environmental Protection Agency identified PCB and DDT hot spots within the estuary, including near Longview, West Sand Island, the Astoria Bridge, and Vancouver (Fresh et al. 2005). Studies in the 1990s found that sediment contamination was highest near urban and industrial areas, with concentrations in excess of levels of concern for DDE (a breakdown product of DDT), PCBs, dioxins and furans, and PAHs (Tetra Tech 1996). Current studies find higher levels of flame retardants (PBDEs), PCBs, and DDT on bed sediment collected near Portland than in sediment collected from other sites in the estuary (Jones et al. 2008).

In addition, emerging contaminants associated with urban development are beginning to be detected in the Columbia River estuary. These include PBDE flame retardants, which have been found in juvenile salmon tissue, their stomach contents, the water column, and on suspended sediment at sites throughout the estuary (Lower Columbia River Estuary Partnership 2007). Caffeine, human and veterinary antibiotics, synthetic musk, and the plasticizer bisphenol A have also been detected in the water of the estuary (Lower Columbia River Estuary Partnership 2007). Although the effects of these compounds are not yet well understood, some of them are suspected hormone disruptors, and juvenile salmon collected from the estuary show evidence of exposure to estrogenic compounds (Lower Columbia River Estuary Partnership 2007). This could be the result of emerging contaminants or more familiar toxic contaminants in the estuary, such as certain pesticides.

***Limiting factors this threat contributes to***: Non-bioaccumulative toxicity, bioaccumulation toxicity, and increased microdetrital inputs.

# Other Threats

## Threat: Riparian Practices

Riparian practices along the estuary mainstem and in tributaries throughout the Columbia River basin have contributed to increases in water temperature in the estuary by changing hydrology and removing riparian habitats (National Research Council 2004) that—among other ecological functions—provide insects and macrodetrital inputs to the food web.

Problematic practices include shoreline modifications, timber harvest, certain agricultural activities within riparian zones, and residential, commercial, and industrial land uses. These activities increase water temperatures, alter hydrology and macrodetrital inputs, and in some cases modify shoreline habitats used by salmonids, especially ocean types (Lower Columbia Fish Recovery Board 2004).

***Limiting factors this threat contributes to***: Sediment/nutrient-related estuary habitat changes, reduced macrodetrital inputs, water temperature, and exotic plants.

### Threat: Ship Wakes

Ships traveling through the Columbia River estuary produce waves and an uprush which, under certain circumstances, causes juvenile salmonids and other fish to become stranded on shore (Bauersfeld 1977). Although Bauersfeld concluded that ship wake stranding was a significant cause of mortality in ocean-type Chinook salmon and other species, other studies have not confirmed the magnitude of this threat. As a part of the U.S. Army Corps of Engineers' channel deepening project, a study is under way that may help characterize the magnitude of ship wake stranding. The purpose of the study is to document ship wake stranding before and after channel deepening. The first half of the study, published in February 2006, documented stranding events at three test sites. The second part of the study will begin after dredging is completed (Pearson et al. 2006). These results should be useful as partial basis for Light Detection and Ranging (LIDAR) analysis and extrapolation of test site mortality throughout the estuary for similar habitat types. Early in 2008, the Port of Vancouver enlisted Entrix, Inc., to perform a spatial analysis of beach susceptibility for the stranding of juvenile salmonids by ship wakes (Pearson 2008). The study examined wave characteristics and the geomorphology of the lower river but did not examine nearshore fish density. The purpose of the study was to estimate the number of miles of shoreline that exhibit traits expected to potentially cause stranding. The study concluded that approximately 33 miles of shoreline between the mouth of the river and the city of Vancouver have shoreline characteristics consistent with stranding (Pearson 2008).

***Limiting factors this threat contributes to***: Stranding.

## Prioritization of Threats

This estuary recovery module establishes priorities for threats by linking them to pertinent limiting factors and estimating their relative contribution to those limiting factors. The threats identified above are well supported in a wide variety of literature sources, including Fresh et al. (2005), Bottom et al. (2005), the "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan" (Northwest Power and Conservation Council 2004), and a variety of more topic-specific primary literature sources.[2] The prioritization of threats, though, is not nearly as well supported, partly because of the limited understanding of how threats contribute to limiting factors and to what degree salmon and steelhead are affected by a given limiting factor. While it is attractive to assume that additional study will fully answer these questions, the biological response to environmental conditions will always be difficult to model because of the tremendous complexities of the physical, biological, and

[2] As with the limiting factors, most of the threats identified in this chapter are not supported by data at the reach or sub-reach scale.

ecological interplay that occurs in the environment. On the other hand, new interest in the estuary and its role in the recovery of listed species in the Columbia River has generated better understanding, and it is likely that uncertainty surrounding threats and limiting factors will continue to lessen.

Table 4-1 demonstrates the relationship between limiting factors and threats by showing which threats are causing which limiting factors and estimating the contribution of each threat to each limiting factor. The presumed relative contribution of a threat to each limiting factor is indicated by the primary, secondary, or tertiary designation. The contribution of each threat to its associated limiting factor(s) is multiplied by the relative importance of that limiting factor to salmonids to yield the threat index score. This score expresses the relative priority of the threat in question. (The relative importance of limiting factors is taken from Table 3-2.)

PC Trask & Associates, Inc., developed the initial threat contribution scores for Table 4-1 by reviewing the extent to which the three main literature sources—and other sources—described relationships between limiting factors and threats or evaluated the contribution of multiple threats to a single limiting factor. Although literature sources were useful in making connections between threats and limiting factors, in many cases the literature did not separate limiting factors from threats or did not attempt to identify and rank the full scope of threats that might be contributing to a particular limiting factor. In nearly all cases, authors discussed cause-and-effect relationships in qualitative language. In some cases, authors described quantitative relationships, as in the relationship between flow regulation and sediment transport. Only a handful of sources estimated priorities for threats.

To supplement information gleaned from the literature, the author talked with regional experts (see Acknowledgements) to identify potential threat contributions not described in the literature. The author also refined the initial scores based on review and input by NMFS Northwest Fisheries Science Center, NMFS Northwest Regional office, Lower Columbia River Estuary Partnership, and Lower Columbia Fish Recovery Board staff. The author, in consultation with staff from the Lower Columbia River Estuary Partnership and NMFS, also made minor adjustments to the scores in response to comments received during the public review period.

**TABLE 4-1**
Linkages Between Limiting Factors and Threats to Ocean- and Stream-Type Salmonids

| Limiting Factor | Threat | Limiting Factor Priority & Numerical Score[a] | Contribution of Threat to Limiting Factor, & Numerical Score[b] | Threat Index[c] |
|---|---|---|---|---|
| Flow-related estuary habitat changes | Climate cycles and global climate change | Top (5) | Secondary (2) | 10 |
| | Water withdrawal | Top (5) | Secondary (2) | 10 |
| | Flow regulation | Top (5) | Primary (3) | 15 |
| Flow-related changes in access to off-channel habitat | Climate cycles and global climate change | Top (5) | Secondary (2) | 10 |
| | Water withdrawal | Top (5) | Secondary (2) | 10 |
| | Flow regulation | Top (5) | Primary (3) | 15 |
| Flow-related plume changes | Climate cycles and global climate change | Top (5) | Secondary (2) | 10 |
| | Water withdrawal | Top (5) | Secondary (2) | 10 |
| | Flow regulation | Top (5) | Primary (3) | 15 |

| Limiting Factor | Threat | Limiting Factor Priority & Numerical Score[a] | Contribution of Threat to Limiting Factor, & Numerical Score[b] | Threat Index[c] |
|---|---|---|---|---|
| | Impaired transport of coarse sediment | Top (5) | Secondary (2) | 10 |
| | Entrapment of fine sediment in reservoirs | Top (5) | Tertiary (1) | 5 |
| Water temperature | Climate cycles and global climate change | Top (5) | Secondary (2) | 10 |
| | Reservoir-related temperature changes | Top (5) | Secondary (2) | 10 |
| | Riparian practices | Top (5) | Secondary (2) | 10 |
| Reduced macrodetrital inputs | Climate cycles and global climate change | Top (5) | Secondary (2) | 10 |
| | Water withdrawal | Top (5) | Secondary (2) | 10 |
| | Riparian practices | Top (5) | Secondary (2) | 10 |
| | Flow regulation | Top (5) | Primary (3) | 15 |
| | Dikes and filling | Top (5) | Primary (3) | 15 |
| Sediment/nutrient-related estuary habitat changes | Impaired transport of coarse sediment | High (4) | Primary (3) | 12 |
| | Entrapment of fine sediment in reservoirs | High (4) | Secondary (2) | 8 |
| | Dredging | High (4) | Secondary (2) | 8 |
| | Pilings and pile dike structures | High (4) | Primary (3) | 12 |
| | Dikes and filling | High (4) | Primary (3) | 12 |
| | Over-water structures | High (4) | Tertiary (1) | 4 |
| | Riparian practices | High (4) | Tertiary (1) | 4 |
| Bankfull elevation changes | Dikes and filling | High (4) | Primary (3) | 12 |
| Native birds | Entrapment of fine sediment in reservoirs | High (4) | Tertiary (1) | 4 |
| | Dredging | High (4) | Secondary (2) | 8 |
| | Altered predator/prey relationships | High (4) | Primary (3) | 12 |
| Native pinnipeds | Altered predator/prey relationships | High (4) | Primary (3) | 12 |
| Non-bioaccumulative toxicity | Agricultural practices | High (4) | Primary (3) | 12 |
| | Urban and industrial practices | High (4) | Primary (3) | 12 |
| Native fish | Entrapment of fine sediment in reservoirs | Medium (3) | Tertiary (1) | 3 |
| | Altered predator/prey relationships | Medium (3) | Primary (3) | 9 |
| Bioaccumulation toxicity | Agricultural practices | Medium (3) | Primary (3) | 9 |
| | Urban and industrial practices | Medium (3) | Primary (3) | 9 |
| Sediment/nutrient-related plume changes | Dredging | Low (2) | Primary (3) | 6 |
| | Pilings and pile dike structures | Low (2) | Secondary (2) | 4 |
| | Dikes and filling | Low (2) | Secondary (2) | 4 |
| Stranding | Ship wakes | Low (2) | Primary (3) | 6 |
| Increased microdetrital inputs | Agricultural Practices | Low (2) | Secondary (2) | 4 |
| | Urban and industrial practices | Low (2) | Secondary (2) | 4 |
| | Increased phytoplankton production | Low (2) | Primary (3) | 6 |
| | Flow regulation | Low (2) | Tertiary (1) | 2 |

| Limiting Factor | Threat | Limiting Factor Priority & Numerical Score[a] | Contribution of Threat to Limiting Factor, & Numerical Score[b] | Threat Index[c] |
|---|---|---|---|---|
| Exotic fish | Entrapment of fine sediment in reservoirs | Lowest (1) | Tertiary (1) | 1 |
| | Over-water structures | Lowest (1) | Secondary (2) | 2 |
| | Pilings and pile dike structures | Lowest (1) | Secondary (2) | 2 |
| | Altered predator/prey relationships | Lowest (1) | Primary (3) | 3 |
| Introduced invertebrates | Altered predator/prey relationships | Lowest (1) | Tertiary (1) | 1 |
| | Ship ballast practices | Lowest (1) | Primary (3) | 3 |
| Exotic plants | Dikes and filling | Lowest (1) | Primary (3) | 3 |
| | Riparian practices | Lowest (1) | Secondary (2) | 2 |
| | Altered predator/prey relationships | Lowest (1) | Primary (3) | 3 |

[a] From Table 3-2.

[b] Indicates how important the threat is in perpetuating the limiting factor:

3 = Threat is a primary cause of the limiting factor. Addressing this threat would significantly improve salmonid performance.

2 = Threat is a secondary cause of the limiting factor. Addressing this threat would improve performance.

1 = Threat is a tertiary cause of the limiting factor. Addressing this threat would benefit performance, but by itself would result in only minor improvement.

[c] Product of the numerical scores for the limiting factor priority and the threat's contribution to the limiting factor. A high threat index score means that the threat is a major contributor to one or more significant limiting factors. A low threat index score means the threat is a small contributor to a minor limiting factor.

Table 4-2 organizes threats by their threat index score, in descending order. However, the state of the science is such that the differentiation of threat priorities in Tables 4-1 and 4-2 should be viewed as reasonable guidance and a set of working hypotheses to be tested and refined through research and evaluation. Given uncertainties about estuarine ecosystems and how they function, some threats that are ranked relatively low in Table 4-2 may eventually prove to have large impacts to the estuary. For example, it is difficult to dispute the importance of flow regulation compared to ship ballast practices. But it is possible that the effects of exotic invertebrates introduced to the estuary through ship ballast practices will significantly degrade the overall health of the estuary ecosystem over time and that this threat will move up in the priority ranking. As another consideration, Tables 4-1 and 4-2 reflect the prioritization of threats across the entire estuary; within each reach, threats could be prioritized differently. A reach-scale analysis of limiting factors and threats was beyond the scope of this document and, in some cases, beyond the limits of currently available science. But such an analysis would be useful as additional scientific information becomes available.

**TABLE 4-2**
Prioritization of Threats to Ocean- and Stream-Type Salmonids

| Threat | Threat Index* | Threat Priority |
|---|---|---|
| Flow regulation | 15 | |
| Dikes and filling | 15 | |
| Altered predator/prey relationships | 12 | |
| Urban and industrial practices | 12 | HIGH |
| Agricultural practices | 12 | |
| Impaired transport of coarse sediment | 12 | |
| Pilings and pile dike structures | 12 | |
| Reservoir-related temperature changes | 10 | |
| Riparian practices | 10 | |
| Climate cycles and global climate change | 10 | |
| Water withdrawal | 10 | |
| Dredging | 8 | |
| Entrapment of fine sediment in reservoirs | 8 | |
| Ship wakes | 6 | |
| Increased phytoplankton production | 6 | LOW |
| Over-water structures | 4 | |
| Ship ballast practices | 3 | |

* From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

# Summary

Chapter 4 provides information on the underlying causes of the factors that influence the viability of ocean- and stream-type ESUs during their residency and migration in the estuary. Analysis of threats is challenging because a single threat often contributes to multiple limiting factors and may originate miles upstream from the estuary. In Chapter 4, threats were identified, described, linked to limiting factors, and prioritized. Chapter 5 turns to management actions, identifying actions that will address threats and thus help reduce risks to the 13 ESA-listed ESUs using the Columbia River estuary.

CHAPTER 5

# Management Actions

Chapters 3 and 4 of this recovery plan module identify factors that currently limit salmonids' biological performance in the estuary and the threats that contribute to those limiting factors. Chapter 5 presents 23 management actions that, together, address the range of threats salmonids in the estuary face, from altered habitat-forming processes to physical structures in the estuary, changes in the food web, and poor water quality. If implemented, the actions presented in this chapter would reduce the impacts of threats to salmonids during their migration and residency in the estuary and plume.

In addition to identifying the management actions, Chapter 5 evaluates them in terms of constraints to implementation, potential improvement in salmonid survival, and cost. More specifically, the chapter discusses each management action's potential benefits and implementation constraints, hypothesizes how benefits could translate into increased survival of salmonids, breaks each action into component projects, and estimates the cost of each project, and thus of each action. Also included is a list of actions that would address threats to salmonids in the estuary but that would need to be implemented outside the estuary, either in estuary tributaries or in upstream areas of the Columbia River basin.

As in other chapters of this recovery plan module, the analysis in Chapter 5 does not fully capture the subtleties of the ecological interactions that influence salmonid survival. Despite continuing research, many aspects of the salmonid life cycle are poorly understood, in part because of the sheer complexity of the ecosystems that salmonids transition into and out of during their lives. The actual relationships among threats and management actions are far more intricate than what is described here. Additionally, given the limits in scientific understanding, there is a degree of uncertainty at each step of the analysis in this chapter. Yet the categories, ratings, and associations presented here are useful tools for discussing complex ecological relationships and comparing possible outcomes of different management actions.

## Identification of Management Actions

For the purposes of this recovery plan module, a management action is any action that has the potential to reduce the impact of human-caused or naturally occurring threats to salmonids while they migrate or rear in the estuary and plume. PC Trask & Associates, Inc., identified management actions using available literature and input from area experts (see Acknowledgements). Key documents used to identify management actions are the "Mainstem Lower Columbia River and Columbia River Estuary Subbasin Plan" (Northwest Power and Conservation Council 2004) and its supplement; *Role of the Estuary in the Recovery of Columbia River Salmon and Steelhead (*Fresh et al. 2005); *Salmon at River's End* (Bottom et al. 2005); and the *2004 FCRPS Biological Opinion on Remand* (National Marine Fisheries Service 2004). Table 5-1 lists threats to salmonids in the estuary and plume and management actions that would address those threats; this information is organized by topic and does not reflect the priority of either threats or management actions.

TABLE 5-1
Management Actions to Address Threats

| | Threat | Management Action |
|---|---|---|
| **Flow-related threats** | Climate cycles and global climate change[2] | **CRE[1]-1:** Protect intact riparian areas in the estuary and restore riparian areas that are degraded.[2]<br>**CRE-2:** Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.[2]<br>**CRE-3:** Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries.[2] |
| | Water withdrawal | ***CRE-3:*** *Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries* |
| | Flow regulation | **CRE-4**: Adjust the timing, magnitude, and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume.<br>***CRE-3:*** *Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries.* |
| **Sediment-related threats** | Entrapment of fine sediment in reservoirs | **CRE-5:** Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume. |
| | Impaired transport of coarse sediment | **CRE-6:** Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.<br>**CRE-8:** Remove or modify pilings and pile dikes with low economic value when removal or modification would benefit juvenile salmonids and improve ecosystem health.<br>***CRE-4:*** *Adjust the timing, magnitude, and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume.* |
| | Dredging | **CRE-7:** Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary. |
| **Structural threats** | Pilings and pile dike structures | ***CRE-8:*** *Remove or modify pilings and pile dikes with low economic value when removal or modification would benefit juvenile salmonids and improve ecosystem health.* |
| | Dikes and filling | **CRE-9:** Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat.<br>**CRE-10:** Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats. |
| | Reservoir-related temperature changes | ***CRE-2:*** *Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.* |
| | Over-water structures | **CRE-11:** Reduce the square footage of over-water structures in the estuary. |

| | Threat | Management Action |
|---|---|---|
| **Food web-related threats** | Increased phytoplankton production | ***CRE-10:*** *Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats.* |
| | Altered predator/prey relationships | **CRE-13:** Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids.<br>**CRE-14:** Identify and implement actions to reduce salmonid predation by pinnipeds.<br>**CRE-15:** Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of invasive plants.<br>**CRE-16:** Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.<br>**CRE-17:** Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.<br>**CRE-18:** Reduce the abundance of shad in the estuary.<br>***CRE-8:*** *Remove or modify pilings and pile dikes with low economic value when removal or modification would benefit juvenile salmonids and improve ecosystem health.* |
| | Ship ballast practices | **CRE-19:** Prevent new introductions of aquatic invertebrates and reduce the effects of existing infestations<br>***CRE-7:*** *Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary.* |
| **Water quality-related threats** | Agricultural practices | **CRE-20:** Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary.[3]<br>***CRE-1:*** *Protect intact riparian areas in the estuary and restore riparian areas that are degraded.*<br>***CRE-9:*** *Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat.* |
| | Urban and industrial practices | **CRE-21:** Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants.<br>**CRE-22:** Restore or mitigate contaminated sites.<br>**CRE-23:** Implement stormwater best management practices in cities and towns.[3]<br>***CRE-1:*** *Protect intact riparian areas in the estuary and restore riparian areas that are degraded.*<br>***CRE-9:*** *Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat.* |
| **Other threats** | Riparian practices | ***CRE-1:*** *Protect intact riparian areas in the estuary and restore riparian areas that are degraded.* |
| | Ship wakes | **CRE-12:** Reduce the effects of vessel wake stranding in the estuary. |

[1] CRE = Columbia River estuary.

[2] Study of the impacts of global climate change is an evolving field, and additional research is needed to understand the phenomenon's likely effects on estuarine habitats and processes with specificity. At this time, the Independent Scientific Advisory Board of the Northwest Power and Conservation Council expects that the regional effects of global climate change in the next century will include more precipitation falling as rain rather than snow, reduced snow pack, and late-summer/early-fall stream flows, and associated rises in stream temperature (Independent Scientific Advisory Board 2007). The climate-related management actions in Table 5-1 reflect these expected impacts. Although the management actions clearly would not change the threat of global climate change itself, they have the potential to lessen its impact on salmonids in the estuary. Even if climate cycles and global climate change have effects different from those assumed in this document, the management actions that Table 5-1 associates with climate would provide benefits to salmonids by addressing other threats, such as water withdrawal, urban and industrial practices, and reservoir heating. All three of the management actions associated with climate in Table 5-1 are associated with other threats listed in Table 5-1.

[3] Unless otherwise noted, the term *best management practices* is used in this document to indicate general methods or techniques found to be most effective in achieving an objective. NMFS envisions that in implementation, specific best management practices would be developed or recommended.

Note: Italics indicate an action's second occurrence in the table, in connection with a different threat.

Given the complexity of the riverine, estuarine, and marine ecosystems that salmon use during their lives, the actual relationships among threats and management actions are more complicated than Table 5-1 suggests. For example, several of the management actions in Table 5-1 are associated with more than one threat (italics indicate an action's second occurrence in the table). This illustrates the complex interplay of ecological processes in the estuary, particularly processes related to flow, sediment, the food web, and water quality, all of which influence salmon survival. Later in this chapter actions are described and analyzed discretely. Some actions are interrelated, both in the problems they attempt to solve and their probable effects. As an example, CRE-2 through CRE-5 (reducing the effects of reservoir heating, protecting/enhancing instream flows influenced by withdrawals and other water management actions in tributaries, adjusting flow timing and magnitude, and addressing entrapment of fine sediments in reservoir) all deal with reservoir and hydrosystem operations. If implemented together, these actions could act in concert to significantly improve water temperature and sediment delivery in the estuary, potentially providing greater benefits through synergistic action than if they were implemented singly. The potential for synergistic effects of management actions is discussed in more detail in Chapter 7.

The estuary recovery module also identifies specific monitoring, research, and evaluation activities appropriate to the 23 management actions. These activities will provide crucial information on the effectiveness of actions that are implemented in the estuary, associated changes in the ecology of the estuary, and scientific uncertainties that affect implementation of the actions. Monitoring, research, and evaluation activities are presented in Chapter 6. Some of these activities are part of the *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program* (Johnson et al. 2008), while others are specific to the management actions in this recovery plan module.

## Other Recommended Management Actions

In many ways, conditions in the estuary are the sum of ecological stressors that exist throughout the Columbia River basin. Although some threats to salmonids in the estuary originate exclusively in the estuary itself (Caspian tern predation is one example), others are the result of activities in estuary tributaries or in upstream areas; examples of such threats are riparian practices and upstream water withdrawals that reduce stream flow in the estuary. Still other threats, such as land use practices that contribute contaminants to the river, originate in all three areas—estuary, estuary tributaries, and upstream. Because of the geographic scope of these threats, fully addressing them will require effort not just in the estuary but throughout the basin.

When it comes to management actions, though, the geographic scope of this estuary recovery plan module is limited. For the most part the module focuses on management actions that can be implemented within the estuary itself and that will address threats that either originate exclusively within the estuary itself or have a significant in-estuary component. The assumption is that threats originating from outside the estuary are affecting local conditions in tributary and upstream areas and that actions to address these threats will be included in recovery plans being developed for upstream salmonid populations.

Even so, the analysis in Chapters 3 and 4 of this recovery plan module and a review of contemporary literature yielded six management actions that would directly affect threats to salmonids in the estuary yet would need to be implemented almost exclusively outside of the estuary or are otherwise beyond the scope of this document:

- Implement hatchery actions as appropriate throughout the Columbia River basin to reduce the threat of density-dependent mortality as a direct result of ecological interactions (disease, predation, or competition for food or space) between hatchery and wild salmonid juveniles using reduced and/or impaired lower river habitats. The magnitude of the ecological interactions as a function of the cumulative effects of large hatchery releases on natural-origin salmonids, both spatially and temporally, is currently an important scientific uncertainty.
- Upgrade up-river irrigation structures to reduce evaporation and conveyance losses and improve estuary instream flows.
- Implement public and private best management and water system conservation practices to maximize the quantity and quality of instream flows entering the estuary.
- Incorporate water availability analysis in land use planning activities to ensure efficient use of water, improve tributary flows, and reduce stream temperatures.
- Protect and restore riparian areas in tributaries to provide shade and future wood sources.
- Reduce inputs of toxic contaminants originating from upstream tributary and mainstem sources.

Because these six actions are outside the geographic scope of the estuary recovery plan module, they are not analyzed in this chapter. Nevertheless, implementation of these six out-of-estuary actions is important to improving the survival of salmonids in the estuary, so it is recommended that the actions be included in recovery plans being developed for upstream areas of the Columbia River basin.

One factor that is beyond the geographic scope of the estuary recovery plan module but is addressed in the module in a limited manner is hydrosystem operations, which affect water temperature, sediment transport, and various other habitat-forming processes and conditions in the estuary. Although actual operation of the hydrosystem occurs outside the estuary, the system's effects are considered in the module because they are such significant determinants of habitat conditions for juvenile salmonids in the estuary. Also, unlike the recommended out-of-estuary actions listed above, hydrosystem operations that affect estuarine habitat are unlikely to be addressed in recovery plans being developed for upstream areas of the Columbia River basin. For these reasons, the estuary recovery plan module includes two management actions (CRE-2 and CRE-4) that focus specifically on hydrosystem operations.

The recommendation of out-of-estuary actions to improve survival in the estuary is another reflection of the interconnectedness of the various ecosystems salmonids use during their life cycles, the power of the river as a connector, and how the effects of problematic upstream activities are manifested—and sometimes magnified—in the estuary.

# Evaluation of Management Actions: Constraints to Implementation

Constraints to implementation are a key factor in evaluating management actions and their likely impacts on salmonids. No management action can benefit salmonids if it cannot be implemented, and in many cases the degree of benefit corresponds to the degree of implementation. For this reason, the 23 management actions identified above are evaluated in terms of the constraints to their implementation, which yields information about the actions' likely outcomes and starts to provide a basis for comparing the probable effectiveness of different actions.

PC Trask & Associates, Inc., performed an initial rating of management action constraints by qualitatively estimating the degree of difficulty in implementing each action, taking into account social, political, and technical factors, including the probable cost of implementation. Staff at the Lower Columbia River Estuary Partnership, NMFS Northwest Fisheries Science Center, NMFS Northwest Regional Office, and Lower Columbia Fish Recovery Board provided input into this process. PC Trask & Associates, Inc., and NMFS also revised some constraint scores in response to the *Federal Register* public comment process. Because the scientific literature generally falls short of prescribing discrete actions to address threats and is even less robust when it comes to evaluating constraints to implementation, the reader should view specific ratings as a qualitative estimate only, but one that is useful in comparing relative implementation constraints across the 23 management actions.

For each management action, Table 5-2 summarizes the primary threat and limiting factors that the action addresses and expresses the significance of those threats and limiting factors in terms of a threat index. (The threat index indicates whether the threat is a major contributor to a significant limiting factor or a minor contributor to a minor limiting factor. The index is useful in distinguishing those actions that, even if they were successful, would affect a relatively small number of fish from those actions that, even if they were only partially implemented or partially successful, would have more profound benefits because they would affect a larger number of fish.) Table 5-2 also provides a score for the potential benefit to salmonids in the estuary if implementation of the action were completely unconstrained, plus a brief rationale for the score.

Assigning a score for potential benefit with unconstrained implementation is just the first step in evaluating management actions. In fact, decisions about management actions will be made within a complex social and political context that includes a wide variety of interests, and it is likely that many of the actions will not be able to be implemented fully because of various technical, financial, political, or social obstacles. To address this issue, Table 5-2 assigns an implementation constraints score to each management action and briefly explains how implementation of the action could be constrained by various factors. It then gives a score that represents the potential benefits of the action if implementation of the action is constrained. By design, the estuary recovery module takes a relatively optimistic view about what is possible in terms of reducing the constraints to implementation of management actions. This means that even the score in Table 5-2 for constrained implementation of an action may represent a higher degree of implementation than is likely to actually occur. However, some constraints may be reduced over time, such as through technology

advances or changes in economic sectors; as a result, some actions may have greater potential for implementation than is represented in this recovery plan module.

The table concludes with a score for potential benefit of each action assuming that implementation of the action is constrained. This score is an attempt to identify more realistically what the results of an action would be given the social, political, and financial climate in which management actions will be decided on, but it also assumes that considerable effort is made to reduce constraints to implementation. Also, the difference in Table 5-2 between potential benefit with unconstrained implementation of an action and potential benefit with constrained implementation is helpful in identifying where it might be worthwhile to expend effort to reduce constraints because the benefits would be great. This topic is discussed more fully in Chapter 7.

The threat index and scoring in Table 5-2 are for the estuary as a whole, instead of by reach, because in most cases the assessment information needed to do a reach-scale analysis currently is lacking. However, the severity of individual threats and limiting factors varies from reach to reach in the estuary, as do the potential benefits of the management actions. It is assumed that implementation of the management actions will involve dialogue and additional evaluation at the reach scale to aid in prioritizing actions and focusing them in the geographical areas where they would be most beneficial.

TABLE 5-2
Constraints to Implementation of Management Actions

## Management Action CRE-1:

Protect intact riparian areas in the estuary and restore riparian areas that are degraded.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Riparian Practices.** Riparian areas provide key ecological functions that affect water temperature, the availability of insects, and macrodetrital inputs to the ecosystem. Riparian areas in the lower Columbia River have been degraded by a number of factors, including shoreline modifications, diking and dike maintenance practices, and activities related to the disposal of dredged material. |
| ***Associated limiting factors*** | | Water temperature, reduced macrodetrital inputs, and exotic plants. |
| ***Threat index[1]*** | 10 | This threat is a secondary contributor to two top-priority limiting factors (water temperature and reduced macrodetrital inputs) and a tertiary contributor to one additional limiting factor. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 4 | Protecting intact riparian areas and restoring degraded riparian areas in priority reaches would provide significant benefits to salmonids by reducing water temperatures and increasing macrodetrital inputs to the system. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 3 | Levels of protection vary across the lower Columbia region. In some cases, riparian areas in cities and counties are protected through regulatory mechanisms such as growth management or shoreline rules. Regulatory tools such as buffer zones along streams can be effective but require broad public support over time. Restoration projects are expensive and can take decades to provide their full benefit to tributaries directly entering the estuary. |
| ***Potential benefits with constrained implementation of action*** | 2 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-2:

Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Reservoir-related temperature changes.** Low-velocity flows and broad surface area exposure in reservoirs increase the temperature of flows in the estuary. Salmonids are cool-water fish that need stream temperatures of 20º C or lower for normal metabolism, growth, disease resistance, and timing of important life functions such as smoltification and adult migration. Salmonids in the estuary are experiencing water temperatures at the upper limit of their tolerance for longer periods and more frequently than they did historically. |
| ***Associated limiting factors*** | | Water temperature. |
| ***Threat index[1]*** | 10 | This threat is a secondary contributor to a top-priority limiting factor. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 3 | Given that at many times during the year water temperatures in the estuary are at or above the upper limits of salmonids' thermal tolerance, any lowering of water temperature could provide significant survival benefits. Water temperatures of below 20º C throughout the year would aid salmonids in carrying out essential physiological processes and life functions. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 5 | Elevated temperatures that result from reservoir heating are difficult to reduce. Temperatures may be influenced by the volume and speed of flows through the hydrosystem and the source of those flows (some impoundments have cooler water than others do). International treaties, conflicting fish management objectives systemwide, the need for flood control, power management, and other factors constrain management of the hydrosystem to allow cooler flows to enter the estuary. |
| ***Potential benefits with constrained implementation of action*** | 2 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-3:

Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries.

| | | |
|---|---|---|
| ***Primary threats this action would address*** | | **Water withdrawal and impaired transport of coarse sediment.** Instream flows in the estuary are important for salmonids because they maintain habitat-forming processes and conditions in the estuary and plume. Transport of sand and gravel from upstream and estuary sources during high flows helps establish and maintain salmonid habitats, contributes to turbidity that shelters salmonids from predation, and influences food sources in the plume. Some instream flows have been established in Columbia River basin tributaries, but others are needed, especially with human population growth in the basin. This action focuses on water withdrawals in tributaries and the mainstem and other tributary flow issues, including tributary hydropower. It complements CRE-4, which focuses on mainstem hydrosystem flow-related issues, such as hydrosystem regulation, to establish incremental flow improvements in the estuary within the context of power generation and flood control. |
| ***Associated limiting factors*** | | Flow-related estuary habitat changes, flow-related changes in access to off-channel habitat, flow-related plume changes, and reduced macrodetrital inputs. |
| ***Threat index[1]*** | 12 | This threat is a secondary contributor to four top-priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 2 | This action contributes incremental instream flow improvements that protect/enhance the flow regime in the estuary and plume and support associated habitat-forming processes. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings); stream-type salmonids in the plume. |
| ***Implementation constraints[3]*** | 5 | Implementation of this action would require the involvement of multiple stakeholders, including irrigation, commercial, industrial, hydrosystem, tribal, Federal, state, and local interests, plus significant public involvement. Establishing protected instream flows is challenging because of competing interests and often takes years. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-4:

Adjust the timing, magnitude, and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume.

| | | |
|---|---|---|
| ***Primary threats this action would address*** | | **Flow regulation and impaired transport of coarse sediment.** The magnitude, frequency, and timing of flows are an important determinant of habitat opportunity for salmonids in the estuary. Salmonids have adapted to historical flows and depend on them to complete their life cycles. The transport of sand and gravel from upstream and estuary sources helps maintain salmonid habitats, contributes to turbidity that shelters salmonids from predation, and influences food sources in the plume. Spring freshets are important habitat-shaping events for the estuary and plume. Improved flow regimes would help ecological processes (and salmonids) by making nutrients and other food sources, such as insects, available in the food web. |
| ***Associated limiting factors*** | | Flow-related estuary habitat changes, flow-related changes in access to off-channel habitat, flow-related plume changes, reduced macrodetrital inputs in the estuary, and sediment/nutrient-related estuary habitat changes. |
| ***Threat index[1]*** | 15 | This threat is a primary contributor to several top-priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 5 | Return to a more natural flow regime would have significant ecosystem benefits and would affect all facets of salmonid life histories expressed in the estuary and plume. Adjustments to the timing, magnitude, and frequency of hydrosystem flows entering the estuary would be likely to have synergistic effects that would increase the benefit of many of the other actions. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies; stream-type juveniles rearing in the plume. |
| ***Implementation constraints[3]*** | 5 | Constraints on hydrosystem operations prevent the return to a natural flow regime in the estuary. Implementation of this action would be limited by international treaties, the need for flood control, fish management objectives systemwide, and power production. However, even slight modifications in the flow regime have the potential to provide significant ecosystem benefits. |
| ***Potential benefits with constrained implementation of action*** | 3 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-5:

Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Entrapment of fine sediment in reservoirs.** Fine sediments originating from upstream sources are trapped in low-velocity impoundments in the Columbia River, and their movement into the estuary and plume has been reduced. This alters processes that form shallow-water habitats, affects food sources, and reduces turbidity that otherwise would shelter salmonids from predation. |
| ***Associated limiting factors*** | | Flow-related plume changes and sediment/nutrient-related estuary habitat changes. |
| ***Threat index[1]*** | 8 | This threat is a secondary contributor to several high-priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 2 | Fine sediment transport processes are important determinants of estuary and plume habitats. Effective mitigation of this threat would reduce predation of salmonids in the main channel and plume and strengthen habitat-forming processes. |
| ***Affected salmonids*** | | Ocean- and stream-type salmonids. |
| ***Implementation constraints[3]*** | 5 | There are no apparent technical solutions to this threat at this time. Mitigation is recommended, but research is needed to identify the magnitude of the threat and potential solutions or mitigation measures. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = significant potential for implementation.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-6:

Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Impaired transport of coarse sediment.** The transport of sand and gravel from upstream and estuary sources is a primary force that influences the creation, maintenance, and distribution of salmonid habitats in the estuary. While there are many potential beneficial uses of dredged materials—including enhanced nourishment of the littoral cell, land creation, property stabilization, and out-of-stream uses—there is also an important ecological need to retain coarse sediments in the estuary for habitat creation and maintenance. |
| ***Associated limiting factors*** | | Sediment/nutrient-related estuary habitat changes and flow-related plume changes. |
| ***Threat index[1]*** | 12 | Although impaired transport of coarse sediment is a primary contributor to a top-priority limiting factor (flow-related plume changes), this management action is likely to have its greatest effect in addressing sediment/nutrient-related estuary habitat changes, a high-priority limiting factor; thus it has a threat index of 12. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 2 | The beneficial use of sand resulting from dredge activities could play an important role in restoring habitat capacity and habitat opportunity in the estuary and plume. The beneficial use of dredged materials to provide sand nourishment could reduce the effects of ship wake stranding, improve habitat for *Americorphium* (a food source for salmonids), and be beneficial in the development of intertidal swamps and marshes and other salmonid habitat features. Sand entering the littoral cell could also have important ecological benefits. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). This particularly applies to ocean-type juveniles because of their significant use of shallow-water habitats and the nearshore environment. |
| ***Implementation constraints[3]*** | 3 | Beneficial uses of dredged materials, such as through littoral cell sand nourishment and direct beach nourishment, are currently receiving significant attention, The most obvious constraint to implementation is identifying funding sources to pay for activities beyond the minimum required by law. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-7:

Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Dredging**. Annual dredge operations maintain a navigational channel that concentrates flows, alters tidal influences, reduces circulation patterns around the estuary, and releases toxic contaminants from substrates. Dredging activities can result in deposited contaminants being disturbed and redistributed throughout the estuary. Dredging activities also result in the entrainment of juvenile salmonids and benthic organisms through the physical removal of sand via pipeline or clamshell dredging. Ship ballast intake may also result in the entrainment of juveniles as ships take on ballast water when exiting port facilities. |
| ***Associated limiting factors*** | | Sediment/nutrient-related estuary habitat changes, native birds, and sediment/nutrient-related plume changes. |
| ***Threat index[1]*** | 8 | As it relates to this action, dredging is a secondary contributor to a high-priority limiting factor (sediment/nutrient-related estuary habitat changes) and thus has a threat index of 8. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 2 | Continued dredge operations represent a physical change to the Columbia River estuary. However, reducing or mitigating the effects of dredging would improve habitat-forming processes that would benefit salmonids. Reduction of entrainment through new technologies or management practices for both dredging and ship ballast intake would reduce mortality of juveniles. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 2 | Dredging activities have been occurring since the 1870s to provide sufficient draft for ships entering the Columbia River and will continue into the foreseeable future. Ongoing maintenance is needed to keep the channel to specifications for ships, and additional dredging will be conducted in the estuary as part of the channel deepening process. Maintaining the navigation channel requires dredging and disposal of large volumes of material (4 to 5 million cubic yards) each year. Changing dredging equipment, ballast water intake screens, and practices to reduce entrainment and habitat effects would be expensive. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*

*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*

*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-8:

Remove or modify pilings and pile dikes when removal or modification would benefit juvenile salmonids and improve ecosystem health.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Pilings and pile dike structures**. Extensive use of pilings and pile dikes has altered sediment accretion and erosion processes and reduced flow circulation through shallow-water habitats in the estuary. Pile structures also have created favorable conditions for predators of salmonids and can reduce physical access to low-velocity juvenile salmonid habitats. In some cases, treated pilings may release toxic contaminants, including PAHs, and it can be beneficial to remove these structures. In other cases, pile structures may protect riparian areas from erosion and wave energy, collect large wood to form complex habitat, and stimulate sediment accretion in the creation of habitat. In these cases, maintenance or modification of existing structures may be beneficial. |
| ***Associated limiting factors*** | | Sediment/nutrient-related estuary habitat changes, sediment/nutrient-related plume changes, exotic fish, native birds, and bioaccumulation toxicity. |
| ***Threat index[1]*** | 12 | This threat is a primary contributor to a high-priority limiting factor (altered predator/prey relationships), a secondary contributor to a high-priority limiting factor (sediment/nutrient-related estuary habitat changes) and two low-priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 4 | Removing many instream structures would improve circulation in shallow-water habitats and eliminate some salmonid predator habitats. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids (yearlings) leaving the heavier flows to forage in shallow waters downstream of pilings and pile dikes; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings); |
| ***Implementation constraints[3]*** | 2 | Only some of the thousands of pilings, pile dikes, and similar structures in the Columbia River estuary are necessary to maintain the shipping channel, protect property, or serve their intended economic use. Removal of superfluous structures generally is restricted only by cost and would be unlikely to affect property rights or the shipping industry. In cases where pile dikes that do aide in navigation are removed, constraints to implementation would include the cost for additional dredging to maintain the channel. |
| ***Potential benefits with constrained implementation of action*** | 2 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-9:

Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Dikes and filling.** High-quality off-channel habitat provides crucial feeding, rearing, and refuge opportunities for juvenile salmonids and supplies macrodetrital inputs to the estuarine food web. Reduced floodplain inundation has limited juvenile salmonids' access to historical wetland and swamp habitat, much of which has been converted to other land uses. Protecting remaining intact and accessible off-channel habitats and restoring accessible but degraded off-channel areas are critical to maintaining key habitats and food sources for juvenile salmonids. |
| ***Associated limiting factors*** | | Reduced macrodetrital inputs, sediment/nutrient-related estuary habitat changes, bankfull elevation changes, sediment/nutrient-related plume changes, and exotic plants. |
| ***Threat index[1]*** | 15 | This threat is a primary contributor to both top-priority and high-priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 5 | Protecting high-quality off-channel areas would help maintain important wetland habitats and supply macrodetrital inputs to the food web and insect food sources for juvenile salmonids—a main component of their diet. Restoring or enhancing accessible but degraded off-channel areas in the estuary represents a largely untapped strategy that could provide similar benefits. Benefits from this strategy likely would be realized more quickly than from the passive restoration associated with CRE-10. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 3 | Regulatory programs often do not effectively protect floodplains from conversion to other uses. The acquisition of land for habitat protection remains controversial in the estuary. Rural county governments see land disappearing off tax rolls and also listen to citizen disapproval of public ownership of land. Land acquisition is expensive and depends on the willingness of landowners to sell. Restoring accessible off-channel habitat also depends on willing landowners .The fact that many habitats already have been converted to other land uses limits opportunities to protect high-quality off-channel habitat. |
| ***Potential benefits with constrained implementation of action*** | 3 | |

[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.

[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[3] Indicates the feasibility of implementing the action.
1 = Current constraints to implementation are minimal.
5 = Current constraints to implementation are significant.

## Management Action CRE-10:

Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Dikes and filling.** Many juvenile salmonids rely on off-channel habitats for feeding and refuge opportunities. Historically, insects and macrodetritus from these habitats were important inputs to the estuarine food web. Dikes, levees, tide gates, and filling have limited the amount and accessibility of key off-channel habitats by reducing floodplain inundation and allowing conversion of land to agricultural, residential, and industrial uses. This action would allow juvenile salmonids access to habitats and food sources that currently are unavailable to them and support improved habitat conditions over time. |
| ***Associated limiting factors*** | | Reduced macrodetrital inputs, sediment/nutrient-related estuary habitat changes, bankfull elevation changes, sediment/nutrient-related plume changes, and exotic plants. |
| ***Threat index[1]*** | 15 | This threat is a primary contributor to both top-priority and high-priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 5 | Establishing or improving access to off-channel areas via dike breaching and similar activities would reclaim habitat that is important to salmonids. Over time, improved hydrology would support reestablishment of wetland vegetation and salmonid food sources in off-channel areas, through passive restoration. In most cases, project benefits would accrue over relatively long periods of time. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 3 | Opportunities to establish or improve access to off-channel habitats are limited because many such habitats already have been filled with dredged materials. Breaching, lowering, or relocating dikes and levees or removing tide gates often requires the cooperation of multiple landowners and may fundamentally alter land uses. The associated habitat restoration is expensive. |
| ***Potential benefits with constrained implementation of action*** | 4 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-11:

Reduce the square footage of over-water structures in the estuary.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Over-water structures.** Over-water structures may provide habitats for predators and affect instream and shoreline plant communities. However, the total surface area of over-water structures in the estuary has not been quantified and the structures' case-by-case functions have not been analyzed. |
| ***Associated limiting factors*** | | Sediment/nutrient-related estuary habitat changes and exotic fish. |
| ***Threat index[1]*** | 4 | This threat is a tertiary contributor to a high-priority limiting factor (habitat changes) and a secondary contributor to one of the lowest priority limiting factors (exotic fish). |
| ***Potential benefits with unconstrained implementation of action [2]*** | 3 | Given the uncertainty about how much of a threat over-water structures actually pose to salmonids, the potential improvement in survival must be considered low pending additional research and analysis. |
| ***Affected salmonids*** | | Ocean-type salmonids (because of their preference for the shallow-water habitats where most structures are located); stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 3 | It is assumed that some over-water structures are more important than others and that removing superfluous or less useful structures would not have deleterious effects on adjacent land uses. Removal of over-water structures that are in currently use would likely require compensation. In some cases, structures such as log rafts could be relocated. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-12:

Reduce the effects of vessel wake stranding in the estuary.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Ship wakes.** Wakes from deep-draft vessels traveling through the estuary wash subyearling salmonids onto shore, leaving them stranded. Factors that affect stranding include beach slope and time of day as well as vessel draft, speed, and hull design. |
| ***Associated limiting factors*** | | Stranding. |
| ***Threat index[1]*** | 6 | This threat is a primary contributor to a low-priority limiting factor. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 2 | The extent of mortality caused by ship wake stranding is unknown. Studies in 1977 and 1994 (Bauersfeld 1977, Hinton and Emmett 1994) reached different conclusions, using different approaches. A soon-to-be-released study by the University of Washington and U.S. Army Corps of Engineers may provide further clarification of the issue. |
| ***Affected salmonids*** | | Ocean-type salmonids (because of their longer estuarine residency times, their relatively small size, and the habitats they prefer); stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 3 | Options for reducing the effects of vessel wake stranding are limited, primarily because of the lost revenues that would result from slower ship travel. Ship traffic through the estuary will continue, ship hull design is unlikely to change, and the speed of ships traveling the estuary may be difficult to alter. Modification of some habitats may be necessary to reduce this threat and would likely be expensive. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-13:

Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Altered predator/prey relationships.** Pikeminnows have always been a significant source of mortality for juvenile salmonids in the Columbia River, but changes in physical habitat, such as the addition of in-water structures, have created more favorable conditions for predation by pikeminnow. Introduced species such as smallmouth bass, walleye, and channel catfish also prey on juvenile salmonids, primarily in the freshwater reaches. |
| ***Associated limiting factors*** | | Native fish and exotic fish. |
| ***Threat index[1]*** | 12 | This threat contributes to many limiting factors, although the management action addresses only the native and exotic fish limiting factors, which have threat indexes of 12 and 3, respectively. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 4 | Ecosystem alterations in the estuary as a result of pikeminnow, smallmouth bass, walleye, and channel catfish are uncertain. Scientists speculate that pikeminnow may be preying on both ocean- and stream-type juveniles. Stream-type juveniles may be affected significantly more than previously thought because evidence suggests that they forage in shallow areas downstream of piling structures. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 2 | Because of their abundance, pikeminnow appear to be a far greater threat to juvenile salmonids than bass, walleye, and channel catfish, at least at this time. Implementation activities to reduce pikeminnow predation are constrained by the challenge of reducing their preferred slack-water habitats. Bounty programs can be effective at removing older pikeminnow, which represent the largest threat to salmonids. Although the introduction of exotic fish to the estuary may be irreversible, there are viable tools for managing smallmouth bass, walleye, and channel catfish; these include habitat management and less restricted harvest management. It is likely that warm-water fishers would actively support maintaining the abundance of these species at current—rather than reduced—levels. |
| ***Potential benefits with constrained implementation of action*** | 2 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-14:

Identify and implement actions to reduce salmonid predation by pinnipeds.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Altered predator/prey relationships.** Pinniped predation on adult salmonids at Bonneville Dam has been estimated at between 0.4 percent (2002) and 4.2 percent (2007) of the spring Chinook and winter steelhead runs, or possibly as high as 8.5 percent and 20 percent, respectively (based on radio-telemetry studies). The extent of predation needs further study and documentation. |
| ***Associated limiting factors*** | | Native pinnipeds. |
| ***Threat index***[1] | 12 | This threat contributes to many limiting factors, although the management action relates only to native pinnipeds. |
| ***Potential benefits with unconstrained implementation of action*** [2] | 3 | Actions to reduce predation by pinnipeds would have moderate impacts on salmonid survival, depending on how many adults are actually being consumed by pinnipeds—a question that remains uncertain. |
| ***Affected salmonids*** | | Ocean- and stream-type salmonids. |
| ***Implementation constraints***[3] | 4 | Methods for reducing salmonid predation by pinnipeds are limited because pinnipeds are protected under the Marine Mammal Protection Act (MMPA). It could take years to amend the act to allow additional pinniped management tools. Non-lethal methods have been only minimally successful, although it is possible that additional testing would identify effective non-lethal methods. In 2008, NMFS granted Washington, Oregon, and Idaho authority to use and evaluate lethal methods of control under Section 120 of the MMPA. |
| ***Potential benefits with constrained implementation of action*** | 2 | |

[1] *From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

[2] *Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

[3] *Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-15:

Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of invasive plants.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Altered predator/prey relationships.** Exotic plants in the estuary often out-compete native plants and change the structure of plant communities. The resulting habitat frequently does not provide the same food or shelter that other species, including salmonids, have adapted to over time. |
| ***Associated limiting factors*** | | Exotic plants. |
| ***Threat index[1]*** | 3 | This threat contributes to many limiting factors, although the management action relates only to exotic plants, one of the lowest priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 2 | Preventing and controlling invasive plants would help maintain the estuarine food web and habitats that juvenile salmonids rely on. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 4 | Controlling existing infestations of certain species is functionally impossible once the species are established. Although landowners are the most important agents in preventing and controlling exotic plant infestations, landowner education is a significant task that requires a large effort. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-16:

Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Altered predator/prey relationships.** Caspian tern predation represents a significant source of mortality for stream-type juveniles migrating to saltwater. Stream-type salmonids are particularly vulnerable because of the timing of their out-migration (during tern nesting season) and their preference for deep-channel habitats near tern nesting sites. |
| ***Associated limiting factors*** | | Native birds. |
| ***Threat index[1]*** | 12 | This threat contributes to many limiting factors, although the management action relates only to Caspian terns. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 5 | Reducing tern predation could have significant effects on the survival of stream-type salmonids, as terns have been documented to consume as much as 3 percent of stream-type juveniles migrating through the estuary. |
| ***Affected salmonids*** | | Stream-type salmonids; ocean-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 2 | Management efforts have helped reduce mortality by relocating terns to nearby habitats. Long-term solutions will require habitat improvements elsewhere for Caspian terns. |
| ***Potential benefits with constrained implementation of action*** | 3 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-17:

Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Altered predator/prey relationships.** Predation by double-crested cormorants represents a significant source of mortality for stream-type juveniles migrating to saltwater. |
| ***Associated limiting factors*** | | Native birds. |
| ***Threat index[1]*** | 12 | This threat contributes to many limiting factors, although the management action relates only to double-crested cormorants. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 4 | Studies indicate that double-crested cormorants prey on salmonid juveniles in the estuary at a rate equal to or greater than the rate by Caspian terns. Cormorants are estimated to have consumed an average of 7 million juvenile salmonids annually over the years 2001 to 2009. |
| ***Affected salmonids*** | | Ocean- and stream-type juvenile salmonids are preyed upon by double-crested cormorants with some fluctuation from year to year. In 2009 double-crested cormorants consumed approximately 11 million juvenile salmonids. |
| ***Implementation constraints[3]*** | 4 | Double-crested cormorants are more difficult to relocate than Caspian terns. Techniques such as the use of decoys and audio playback have not been as effective compared to terns. Perch habitats are plentiful enough in the estuary that removal of pile dikes and other structures may not be an effective tool. |
| ***Potential benefits with constrained implementation of action*** | 2 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-18:

Reduce the abundance of shad in the estuary.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Altered predator/prey relationships.** Shad returns to the Columbia River number approximately 4 million annually. Shad's effects on the estuary ecosystem and salmonids are poorly understood. However, shad are an introduced species and their biomass alone represents a threat to trophic relationships in the Columbia River. |
| ***Associated limiting factors*** | | Exotic fish. |
| ***Threat index[1]*** | 3 | This threat contributes to many limiting factors, although the management action relates only to shad. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 2 | The impacts of shad in the estuary are unclear. However, it is likely that reducing shad numbers would have some benefits for salmonids. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints[3]*** | 5 | Shad are thought to have permanently altered the estuary ecosystem, and their complete removal from the estuary is neither practical nor feasible. Effective management tools to limit shad productivity in the Columbia River basin currently are not available. Research is needed in the near term to determine the significance of this threat and identify potential management actions to manage the abundance of shad. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-19:

Prevent new introductions of aquatic invertebrates and reduce the effects of existing infestations.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Ship ballast practices.** Ship ballast water is responsible for the introduction of non-native aquatic invertebrates in the estuary. The effects of these introductions are poorly understood, but it is likely that exotic invertebrates disrupt food webs and out-compete juvenile salmonids' native food sources. |
| ***Associated limiting factors*** | | Introduced invertebrates. |
| ***Threat index***[1] | 3 | This threat is a primary contributor to one of the lowest priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action*** [2] | 2 | Reducing the impacts of non-native aquatic invertebrates would help maintain traditional salmonid food sources and the trophic relationships that salmon have adapted to. |
| ***Affected salmonids*** | | Ocean-type salmonids; stream-type salmonids displaying less dominant life history strategies (e.g., early and late fingerlings and subyearlings). |
| ***Implementation constraints***[3] | 4 | Improvements in ship ballast practices have already been implemented by the industry as a result of new regulations, and stricter regulations are currently being debated at the Federal level. However, there are inherent challenges in managing ballast water that contains organisms from other ecosystems. Also, once non-native aquatic invertebrates have been introduced, they represent a permanent alteration of the ecosystem and opportunities to reduce their effects may be few. Current understanding of how the estuary ecosystem is affected by introductions of exotic invertebrates is very limited. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

[1] *From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

[2] *Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

[3] *Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-20:

Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary.[1]

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Agricultural practices.** Fertilizers include different forms of nutrients that are important for plant growth. When fertilizers make their way to the estuary through overland runoff, they contribute nutrients to the estuary that increase phytoplankton production, alter the food web, and in some instances depress dissolved oxygen levels. Water-soluble contaminants such as simazine, atrazine, chlorpyrifos, metolachlor, diazinon, and carbaryl enter the estuary as a result of tributary and upstream agricultural practices. DDT and PCBs have been detected at elevated levels in the estuary. These and other agricultural contaminants can cause salmonid mortality through bioaccumulation or non-bioaccumulative toxicity. |
| ***Associated limiting factors*** | | Non-bioaccumulative toxicity, bioaccumulation toxicity, and increased microdetrital inputs. |
| ***Threat index*** [2] | 12 | This threat is a primary contributor to a high-priority limiting factor (non-bioaccumulative toxicity) and a medium-priority limiting factor. |
| ***Potential benefits with unconstrained implementation of action*** [3] | 3 | Reducing the level of pesticides and herbicides in the estuary would improve survival by reducing ocean-type salmonids' acute and chronic exposure to toxic contaminants and stream-type salmonids' acute exposure. |
| ***Affected salmonids*** | | Ocean- and stream-type salmonids. |
| ***Implementation constraints***[4] | 4 | Impacts from pesticides and fertilizers have lessened dramatically since the 1950s as a result of new application technologies, new products, and better understanding and regulation of these toxins. More extensive compliance with existing regulations and usage guidelines, along with development of additional best management practices, could further reduce the impacts of pesticides and fertilizers. The integration of new practices can be expensive and time-consuming. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] The term best management practices is used here to indicate general methods or techniques found to be most effective in achieving an objective. NMFS envisions that in implementation, specific best management practices would be developed or recommended.*

*[2] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[3] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[4] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-21:

Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Urban and industrial practices.** The estuary has been affected by historical and current releases of toxic contaminants, including industrial and commercial pollutants such as PCBs and PAHs. These substances have been found near Portland, Vancouver, Longview, and Astoria. Studies have demonstrated significant juvenile mortality in the estuary as a result of toxic contaminants. In addition, urban and industrial effluent and stormwater runoff are principal sources of nutrients that can support increased phytoplankton levels. |
| ***Associated limiting factors*** | | Non-bioaccumulative toxicity, bioaccumulation toxicity, and increased microdetrital inputs. |
| ***Threat index[1]*** | 12 | This threat is a primary contributor to high- and medium-priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 4 | Reducing sources of pollutants would lower water temperature, nutrient loading, and the amount of toxic contaminants in the estuary. This would improve both habitat capacity in the estuary and the fitness level of salmonids. |
| ***Affected salmonids*** | | Ocean- and stream-type salmonids (particularly ocean types because of their longer residency in the estuary). |
| ***Implementation constraints[3]*** | 4 | While some discharges of industrial and commercial pollutants are permitted, others are not. Efforts to reduce industrial and commercial pollutants are already under way, and there is potential to reduce point-source emissions. Efforts to reduce sources of pollutants are expensive and time-consuming and often have a negative economic effect on operations. |
| ***Potential benefits with constrained implementation of action*** | 3 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-22:

Restore or mitigate contaminated sites.

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Urban and industrial practices.** The estuary has been affected by historical and current releases of toxic contaminants, including industrial and commercial pollutants such as PCBs and PAHs. These substances have been found near Portland, Vancouver, Longview, and Astoria. Studies have demonstrated significant juvenile mortality in the estuary as a result of toxic contaminants. The action is intended to address the need to monitor the entire estuary for contaminants; however, actual restoration activities are feasible only in specific reaches. |
| ***Associated limiting factors*** | | Non-bioaccumulative toxicity and bioaccumulation toxicity. |
| ***Threat index[1]*** | 12 | This threat is a primary contributor to high- and medium-priority limiting factors. |
| ***Potential benefits with unconstrained implementation of action [2]*** | 5 | Reducing toxic contaminants in the estuary would improve both habitat capacity and the fitness level of salmonids. |
| ***Affected salmonids*** | | Ocean- and stream-type salmonids (particularly ocean types because of their longer residency in the estuary). |
| ***Implementation constraints[3]*** | 3 | Monitoring activities are already occurring; however, actual restoration of contaminated sites is expensive and technically challenging in many cases. In cases where restoration is not feasible, the effects of contaminated sites should be mitigated. |
| ***Potential benefits with constrained implementation of action*** | 3 | |

*[1] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[2] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[3] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

## Management Action CRE-23:

Implement stormwater best management practices in cities and towns.[1]

| | | |
|---|---|---|
| ***Primary threat this action would address*** | | **Urban and industrial practices.** Municipal stormwater runoff can convey nutrients and toxic contaminants to the estuary, reduce groundwater recharge, and increase the "flashiness" of stream flows. Although cities and towns in the Columbia River basin generally have programs to reduce the impacts of stormwater runoff, stormwater best management practices have not been universally accepted or implemented throughout the basin. |
| ***Associated limiting factors*** | | Non-bioaccumulative toxicity, bioaccumulation toxicity, and increased microdetrital inputs. |
| ***Threat index[2]*** | 9 | This threat is a secondary contributor to a medium-priority limiting factor as it relates to this management action. |
| ***Potential benefits with unconstrained implementation of action*** [3] | 2 | Identifying and implementing stormwater best management practices throughout the Columbia River basin would improve conditions and provide a net benefit to salmonids in the estuary through a more normal flow regime, reduced exposure to contaminants, and lower water temperatures. |
| ***Affected salmonids*** | | Ocean- and stream-type salmonids (particularly ocean types because of their longer residency in the estuary). |
| ***Implementation constraints[4]*** | 2 | Some cities lack the resources or will to implement or enforce stormwater best management practices. The benefits of improved stormwater practices generally are associated only with new development and do not offset the full impact of the impervious surfaces in those developments, or the existing impervious surfaces in areas that have already been developed. |
| ***Potential benefits with constrained implementation of action*** | 1 | |

*[1] The term best management practices is used here to indicate general methods or techniques found to be most effective in achieving an objective. NMFS envisions that in implementation, specific best management practices would be developed or recommended.*

*[2] From Table 4-1. Indicates the significance of the associated limiting factor and the threat's contribution to that limiting factor. High numbers indicate threats that have a major contribution to high-priority limiting factors; lower numbers indicate threats that have a minor contribution to low-priority limiting factors. Numbers indicate the highest score per threat category and do not account for multiple limiting factor contributions.*

*[3] Estimate of the expected benefits to salmonids (ocean- and stream-types combined) if the action were fully implemented, with no constraints.*
*1 = very low benefits.*
*5 = very high benefits.*

*[4] Indicates the feasibility of implementing the action.*
*1 = Current constraints to implementation are minimal.*
*5 = Current constraints to implementation are significant.*

Table 5-2 estimates the potential of each management action to benefit salmonids under two different implementation scenarios. Assuming that implementation of most actions is significantly constrained, which management actions would be likely to result in the greatest survival improvements?

In partial answer to this question, Table 5-3 summarizes the potential benefits of each action under both unconstrained and constrained implementation scenarios. It is tempting to sort the actions in Table 5-3 by potential benefit with constrained implementation and view the sorted list as a prioritized list of management actions, with the actions at the top being those predicted to have the greatest benefits. Although Table 5-3 does provide insight into the relative benefits of the various management actions, it is perhaps most useful as a means of contrasting the benefits that might be achieved with unconstrained implementation of an action with the benefits that might be achieved under a more likely scenario of constrained implementation.

To provide greater insight into the relative benefits of each management action, PC Trask & Associates, Inc., developed a second analysis based on survival improvement targets. This analysis, which is presented in the next section of the document, is more refined and specific than the analysis in Table 5-3. For instance, it focuses more on how the potential benefits of the 23 management actions would compare to each other and on the survival benefits that might be gained from each action. It also evaluates the benefits of each action to both ocean- and stream-type salmonids.

TABLE 5-3
Summary of Constraints to Implementation of Management Actions

| Number | Action Description | Benefit with Unconstrained Implementation of Action[1] | Benefit with Constrained Implementation of Action[2] |
|---|---|---|---|
| CRE-01 | Protect intact riparian areas in the estuary and restore riparian areas that are degraded. | 4 | 2 |
| CRE-02 | Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures. | 3 | 2 |
| CRE-03 | Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries. | 2 | 1 |
| CRE-04 | Adjust the timing, magnitude, and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume. | 5 | 3 |
| CRE-05 | Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume. | 2 | 1 |
| CRE-06 | Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially. | 2 | 1 |

| Number | Action Description | Benefit with Unconstrained Implementation of Action[1] | Benefit with Constrained Implementation of Action[2] |
|---|---|---|---|
| CRE-07 | Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary. | 2 | 1 |
| CRE-08 | Remove or modify pilings and pile dikes when removal or modification would benefit juvenile salmonids and improve ecosystem health. | 4 | 2 |
| CRE-09 | Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat. | 5 | 3 |
| CRE-10 | Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats. | 5 | 4 |
| CRE-11 | Reduce the square footage of over-water structures in the estuary. | 3 | 1 |
| CRE-12 | Reduce the effects of vessel wake stranding in the estuary. | 2 | 1 |
| CRE-13 | Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids. | 4 | 2 |
| CRE-14 | Identify and implement actions to reduce salmonid predation by pinnipeds. | 3 | 2 |
| CRE-15 | Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of invasive plants. | 2 | 1 |
| CRE-16 | Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island. | 5 | 3 |
| CRE-17 | Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations. | 4 | 2 |
| CRE-18 | Reduce the abundance of shad in the estuary. | 2 | 1 |
| CRE-19 | Prevent new introductions of invertebrates and reduce the effects of existing infestations. | 2 | 1 |
| CRE-20 | Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary. | 3 | 1 |
| CRE-21 | Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants. | 4 | 3 |
| CRE-22 | Restore or mitigate contaminated sites. | 5 | 3 |
| CRE-23 | Implement stormwater best management practices in cities and towns. | 2 | 1 |

[1]Estimate of potential benefit if action is fully implemented, with no constraints.
1 = very low benefits.
5 = very high benefits.

[2]Estimate of potential benefit assuming that implementation is constrained.
1 = very low benefits.
5 = very high benefits.

# Evaluation of Management Actions: Survival Improvement Targets

The Columbia River estuary and plume are only two of many ecosystems that salmonids travel in their complex and lengthy journey from headwaters to ocean and back again. Mortality occurs at every stage of this journey. Each year, scientists from the NMFS Northwest Fisheries Science Center estimate the number of juvenile salmonids that enter the estuary from upstream of Bonneville Dam and from estuary tributaries. For 2006, scientists from NMFS estimated that about 168 million juvenile salmonids (both wild and hatchery) would enter the estuary (Ferguson 2006b). Some years later, the surviving fish return to the estuary in varying numbers, with the average return in the last 10 years being approximately 1.7 million fish; roughly 65 to 75 percent of those fish are of hatchery origin.[1] This means that less than 1 percent of the juveniles that enter the estuary are returning as adults.

## Estimating Juvenile Mortality in the Estuary and Plume

How much juvenile mortality is occurring in the estuary and plume? The answer to this question is fundamental to developing an understanding of the role the estuary will play in the recovery of salmonid populations basinwide. The answer also is critical in evaluating the benefits and costs of potential management actions because it helps establish the level of effort needed to offset threats to salmonids in the estuary. Unfortunately, determining how much juvenile mortality is occurring in the estuary and plume is challenging for scientists. Counting juveniles in the Columbia River estuary and plume is problematic because available tracking technologies are limited, and it is difficult to monitor juveniles—which tend to move in and out of saltwater—in large, high-energy sites such as the mouth of the Columbia River.

However, some efforts have been made to separate mortality that occurs in the estuary and plume from mortality that occurs in the ocean. One such effort has been the underlying assumptions in the Ecosystem Diagnosis and Treatment (EDT) model, which is used extensively throughout the Columbia River basin. For juveniles entering the estuary from tributaries to the lower Columbia River, EDT assumes mortality rates in the estuary and plume of between 18 and 58 percent, depending on the salmonid species and the amount of time juveniles spend in the estuary (Lower Columbia Fish Recovery Board 2004). In a study of juvenile mortality in the estuary, Schreck et al. (2006) estimated spring/summer Chinook mortality at between 11 and 17 percent, largely from avian predation.

In addition, research is under way by NMFS, the U.S. Army Corps of Engineers, and Battelle Laboratories to estimate the survival rate of juvenile salmonids in the lower Columbia River. This research involves new technologies for miniaturizing acoustic tags to a size capable of tracking yearling and subyearling juveniles. Current technology developed for the project allows for the tracking of subyearlings of sizes down to approximately 90 mm. Results for the first year (2005) indicated an approximate range of survival of 65 to 75 percent for subyearlings and yearlings during their residency in the estuary (Ferguson 2006a). It is probable that actual survival rates are lower than these preliminary estimates suggest

[1] This is an informal estimate; determining the ratio of hatchery-origin fish with more certainty would require stock-by-stock run calculations averaged over many years.

because the research did not address mortality among juveniles smaller than 90 mm or mortality occurring in the plume and nearshore. The studies above have not been conclusive, and separating estuarine and ocean mortality for juvenile salmonids in the Columbia River remains significant challenge.

Some specific estimates of salmonid mortality are known in the estuary; they include estimates for double-crested cormorants and Caspian terns. For other threats to salmonids, such as toxic contamination, ship wake stranding, and pinniped predation, information on mortality in the estuary is incomplete or relatively new in the literature. Still other threats, especially those related to the food web, are poorly understood and have no mortality estimates associated with them, although in some cases the change in conditions from the historical template to the present has been well documented.

## Establishing Survival Improvement Targets

An important goal of this estuary recovery plan module is to estimate the potential benefits—in terms of increased survival of salmonids in the estuary—that could result from the implementation of different management actions. To accomplish this goal, PC Trask & Associates, Inc., used available information about limiting factors, threats, and constraints to the implementation of management actions to assign benefits that could possibly result from different actions.

If scientific understanding of the relationships between ecological conditions and biological responses in estuarine systems were robust, it would be attractive to assign specific mortality rates to each of the factors limiting salmonids' biological performance in the Columbia River estuary. Then one could follow a deterministic logic path that associates mortality rates with specific threats, relates the mortality rates to management actions, and ultimately arrives at an estimate of the survival improvement that would be likely to result from each action. This is not possible at this time, and it will likely not be possible until there have been significant advances in scientific understanding of the complex estuarine environment.

To compensate for the lack of detailed information on mortality in the estuary, PC Trask & Associates, Inc., established targets for improved survival of wild ESA-listed salmonids rearing and migrating in the estuary and plume, assuming that the implementation of management actions is constrained to the degree indicated in Table 5-2. PC Trask & Associates, Inc., then allocated these survival targets to individual management actions. These targets are intended to serve as a planning tool useful in characterizing the potential results of actions and describing the level of effort needed to recover salmonids.

The primary purpose of the survival improvement targets is to help compare the potential benefits of different management actions, particularly actions that partially address major limiting factors versus actions that fully address minor limiting factors. In addition, the survival improvement targets provide insight into the specific survival benefits of each action and the differential benefits of each action to stream- and ocean-type salmonids. Numerically, the survival improvement targets in this chapter were based on an estimate of the number of naturally produced ESA-listed ocean- and stream-type juvenile salmonids entering the estuary. The total number of naturally produced ESA-listed juvenile salmonids

estimated to enter the estuary in 2006 was approximately 39 million (Ferguson 2006b).[2] Of these, approximately 25 million were estimated to be ocean type and 14 million were estimated to be stream type.

To establish survival improvement targets, PC Trask & Associates, Inc., developed some assumptions about the overall mortality of juvenile salmonids during estuary and plume residency. Ocean-type juveniles were assumed to have an overall mortality rate of 50 percent during their estuary residency; this includes the 35 percent mortality suggested by the unpublished micro-acoustic tagging research (Ferguson 2006a) plus an additional 15 percent to account for juveniles too small to be tracked. Stream-type juveniles were assumed to have an overall mortality rate of 40 percent during estuary and plume residency. This rate was based on the 25 percent mortality found in the micro-acoustic tagging research (Ferguson 2006a) plus an additional 15 percent to account for mortality occurring in the plume, which was not part of study. These assumptions about estuary mortality are based on best professional judgment by PC Trask & Associates, Inc., after a review of pertinent literature and discussions with subject matter experts, including scientists at the NMFS Northwest Fisheries Science Center.

Table 5-4 shows the number of wild, ESA-listed ocean- and stream-type juveniles thought to be entering the lower Columbia estuary and plume, their estimated mortality and survival rates based on the assumptions above, and the number of juveniles estimated to survive their journey through the estuary and plume—again, based on the assumptions above.

TABLE 5-4
Estimated Mortality Rates, Survival Rates, and Survival Improvement Targets for Wild, ESA-Listed Juveniles

| Type | Juveniles Entering Estuary* | Assumed Mortality Rate | Assumed Survival Rate | Estimated Number of Juveniles Exiting Estuary and Plume* | Survival Improvement Target (20 percent)** |
|---|---|---|---|---|---|
| Ocean Type | 25 million | 50% | 50% | 12.5 million | 2.5 million*** |
| Stream Type | 14 million | 40% | 60% | 8.4 million | 1.68 million*** |

* = Wild, ESA-listed juveniles.

** = Twenty percent of the estimated number of juveniles exiting the estuary and plume; this target represents additional fish surviving their estuary and plume residency.

*** These numbers are used to characterize the potential, relative benefits of implementing various management actions and do not represent actual numbers of additional fish expected to survive.

Table 5-4 also presents survival improvement targets for ocean- and stream-type salmonids in the estuary and plume. For planning purposes only, this estuary recovery plan module selects 20 percent as a target for improvement in the survival rate of wild, ESA-listed ocean- and stream-type juveniles in the estuary and plume. Twenty percent represents a hypothetical level of improvement that might be realized through the implementation of the management actions, assuming that considerable effort is expended to help offset constraints to implementation, such that threats and limiting factors are reduced. For ocean types, increasing survival by 20 percent would result in a total of 15 million juveniles exiting

[2] Current scientific information on the effects of limiting factors and actions does not differentiate between hatchery- and natural-origin salmon and steelhead, or between salmon and steelhead that are listed under the ESA and those that are not. Because ESA recovery is determined by the status of natural-origin fish, the intent of the module is to improve the estuarine survival of naturally produced, ESA-listed salmon and steelhead. Naturally produced fish are the focus of the analysis of survival improvement targets because they are the focus of the module.

the estuary and plume—2.5 million more juveniles than the current estimate of 12.5 million. For stream types, a 20 percent improvement would equal 10.08 million—1.68 million additional juveniles beyond the current 8.4 million that are estimated to exit the estuary and plume. Thus the survival improvement targets for ocean- and stream-type salmonids are 2.5 million and 1.68 million, respectively, as shown in Table 5-4. Targets for both types were set at 20 percent to avoid the appearance of a false level of precision in establishing them. Ocean-type juveniles were assumed to incur more mortality in the estuary and nearshore compared to stream types. Stream types were assumed to incur less mortality in the estuary than ocean types but significantly more mortality in the plume.

PC Trask & Associates, Inc., selected the 20 percent survival improvement number for ocean- and stream-type juvenile salmonids based on a qualitative analysis of the level of improvement that reasonably and plausibly might be expected if the 23 management actions were implemented. In establishing the 20 percent target, PC Trask & Associates, Inc., reviewed existing management plans, other literature sources, and the constraints analysis in Table 5-2. However, setting 20 percent as the target for improvement, rather than 15 or 30 percent, is inherently subjective and relies in part on the following assumptions:

- That estuary mortality for juveniles (currently between 40 and 50 percent, depending on population) can be reduced by initiating restoration projects and reducing uncertainties through research and monitoring
- That mortality rates associated with certain threats, such as Caspian terns and cormorants, are well understood and will be lessened through actions specified in management plans that are reasonably likely to be implemented
- That all of the actions identified in this chapter are implemented to a reasonable degree and historical and current constraints to action implementation are thoroughly challenged

Actual improvements in survival will depend on which management actions are implemented, how fully they are implemented, and their efficacy—factors that at this point are open to interpretation and can be qualitatively estimated only. Although the 20 percent targets for ocean- and stream-type salmonids are intended to be reasonable and plausible given the information available to date, open technical, political, and social discussion could refine the targets until science can substantiate them.

The survival improvement targets in Table 5-4 were developed using ocean- and stream-type life history strategies to characterize the 13 ESUs in the Columbia River basin. As a result, the survival improvement targets do not account for important variations found at the ESU, population, and subpopulation scales. For example, not all ocean-type ESUs in the Columbia River basin exhibit the same run timing, size at estuary entry, or use of particular habitats (Fresh et. al 2005). In fact, this variability in estuarine use by the ESUs is fundamental to the member/vagrant theory proposed by the NMFS Northwest Fisheries Science Center and a central premise of the estuary recovery plan module (see Chapter 2 for more information on the member/vagrant theory). Although genetic and spatial diversity are not explicitly accounted for in survival improvement targets, the suite of management actions identified in the estuary recovery plan module is intended to collectively address all life history strategies historically expressed in the estuary and plume. This further

emphasizes that the survival improvement targets are best viewed as a planning tool only. In reality, there will be significant variability among ESUs, populations, and subpopulations in how much additional survival might result from improvements in estuary and plume habitat.

## Assigning Survival Improvement Targets to Recovery Actions

The usefulness of the 20 percent target lies not in the 20 percent number itself, but in the distribution of the targets (2.5 million ocean-type juveniles and 1.68 million stream-type juveniles) across the various management actions, as a way of characterizing the relative benefits of the various management actions.[3] Table 5-5 shows this allocation of survival improvement targets to the 22 management actions for juvenile salmonids.[4] In cases where there is good scientific literature that supports the allocation of survival targets, as with terns and cormorants, PC Trask & Associates, Inc., used that information as a basis for the analysis in Table 5-5. In other cases, such as reservoir-related temperature changes, PC Trask & Associates, Inc., estimated survival improvements based on literature discussion of related limiting factors and threats. The reader should view the resulting survival improvement targets as the product of a planning exercise, not a representation of deterministically based estimates. (Appendix B presents more information on how PC Trask & Associates, Inc., allocated survival improvement targets to the different actions.)

Although the survival improvement targets in Table 5-5 are estimates only, they complement the analysis summarized in Table 5-3.[5] In addition, they provide a useful way to show the potential magnitude of juvenile survival at the action scale relative to other actions. The survival improvement targets illustrate how a small increment of implementation of a far-reaching action could offer significantly more potential for recovery than full implementation of an action that is more limited in scope. Comparison of Tables 5-3 and 5-5 and the cost estimates that are developed in the next section form the basis for prioritization of actions in Chapter 7, "Perspectives on Implementation."

A special case in assigning survival improvement targets to actions are those actions (CRE–01 and CRE–09) that use land protection as a means of achieving the target. In theory, protection projects contribute only to maintenance of baseline conditions and not to recovery. However, the estuary recovery plan module does assign a portion of the survival improvement targets to protection projects. The reasoning here is that without protection of baseline environmental conditions, significantly more effort would be required in restoration projects to offset the continued loss of functioning habitat that would result from increases in the human population and corresponding conversion of habitats to economically beneficial land uses. Thus, assigning survival improvement targets to

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[3] Although for the purposes of this analysis 20 percent is considered a hypothetical number, it is a plausible number. The 20 percent figure is based on overall estimates of juvenile mortality in the estuary, known mortality that can be attributed to specific threats, and professional judgment regarding the efficacy of the different management actions and the likelihood that constraints to their implementation can be overcome.

[4] Although the survival improvement targets are expressed in terms of numbers of natural-origin ESA-listed fish, this is simply to illustrate the potential benefits of actions, not to analyze differential benefits to natural-origin listed fish versus unlisted or hatchery-origin fish; what is important is the allocation of relative benefits among the management actions.

[5] Table 5-2 contrasts the difference between constrained and unconstrained implementation of an individual action, while Table 5-5 compares potential benefits across the entire set of actions. Given the two tables' different purposes, there is not a mechanistic relationship between them. However, there is a rough correlation between the potential benefits of constrained implementation in Table 5-2 and where an action falls in the relative rankings presented in Table 5-5.

protection projects reflects the value of avoiding the additional effort that would be required to restore functioning habitats lost because they were not protected.

## Uses of the Survival Improvement Targets

The purpose of the survival improvement targets in Table 5-5 is to address a particular planning challenge in the estuary module: how to compare the potential benefits of management actions that are disparate in their scope and feasibility, especially when scientific information about the causes of salmonid mortality in the estuary is incomplete. In the absence of comprehensive scientific data, the targets provide a useful framework for evaluating the relative merits of different actions. However, survival improvement targets do not represent actual numbers of fish.

For example, it would be inappropriate to use the survival improvement targets to estimate total juvenile mortality in the estuary, attribute a level of mortality to a specific limiting factor or threat, or calculate "per-fish" costs of actions. Because the survival improvement targets are not scientifically derived, they have limited use for life-cycle modeling. On the other hand, the targets could serve as a starting point for life-cycle modeling in the absence of rigorous data.

It also would be unwise to predict specific outcomes of an action or suite of actions based solely on the survival improvement targets. Although it would be appropriate to use the targets to guide expenditures and the selection of individual projects that are consistent with the module's management actions, monitoring should accompany any implementation of those projects—to evaluate their effectiveness, test the assumptions underlying the targets, and provide a basis for refining them.

Because the survival improvement targets are a tool for comparing the relative benefits of actions, they are particularly useful in weighing the trade-offs involved in implementing some actions but not others, or implementing actions only partially. For example, in theory, if a certain action were implemented partially or not at all, the potential 20 percent gain in the number of wild, ESA-listed juveniles leaving the estuary and plume could not be achieved unless other actions were implemented to a greater extent than envisioned in the module, to compensate. Survival improvement targets provide a way of evaluating various scenarios for implementation. This is critical because the implementation of every action already is constrained (often significantly) and, in most cases, the opportunities to remove constraints and implement actions more fully are limited.

TABLE 5-5
Survival Improvement Targets Allocated to Management Actions[1]

| Number | Action Description | Survival Improvement Target[1] with Constrained Implementation (numbers of wild, ESA-listed fish) | | | |
|---|---|---|---|---|---|
| | | Ocean Type[1] | % of Total Improvement Target | Stream Type[1] | % of Total Improvement Target |
| CRE-01 | Protect intact riparian areas in the estuary and restore riparian areas that are degraded. | 150,000 | 6% | 100,000 | 6% |
| CRE-02 | Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures. | 90,000 | 4% | 20,000 | 1% |
| CRE-03 | Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries. | 25,000 | 1% | 20,000 | 1% |
| CRE-04 | Adjust the timing, magnitude, and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume. | 225,000 | 9% | 125,000 | 7% |
| CRE-05 | Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume. | 5,000 | <1% | 5,000 | <1% |
| CRE-06 | Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially. | 50,000 | 2% | 15,000 | <1% |
| CRE-07 | Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities in the estuary. | 8,000 | <1% | 10,000 | <1% |
| CRE-08 | Remove or modify pilings and pile dikes when removal or modification would benefit juvenile salmonids and improve ecosystem health. | 150,000 | 6% | 100,000 | 6% |
| CRE-09 | Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat. | 400,000 | 16% | 150,000 | 9% |
| CRE-10 | Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats. | 450,000 | 18% | 100,000 | 6% |
| CRE-11 | Reduce the square footage of over-water structures in the estuary. | 25,000 | 1% | 3,000 | <1% |
| CRE-12 | Reduce the effects of vessel wake stranding in the estuary. | 55,000 | 2% | 2,000 | <1% |

| Number | Action Description | Survival Improvement Target[1] with Constrained Implementation (numbers of wild, ESA-listed fish) | | | |
|---|---|---|---|---|---|
| | | Ocean Type[1] | % of Total Improvement Target | Stream Type[1] | % of Total Improvement Target |
| CRE-13 | Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids. | 140,000 | 6% | 122,000 | 7% |
| CRE-14 | Identify and implement actions to reduce salmonid predation by pinnipeds. | N/A[2] | N/A | 1,034[2] | N/A |
| CRE-15 | Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of invasive plants. | 20,000 | <1% | 15,000 | <1% |
| CRE-16 | Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island. | 2,000 | <1% | 350,000 | 21% |
| CRE-17 | Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations. | 2,000 | <1% | 250,000 | 15% |
| CRE-18 | Reduce the abundance of shad in the estuary. | 5,000 | <1% | 5,000 | <1% |
| CRE-19 | Prevent new introductions of aquatic invertebrates and reduce the effects of existing infestations. | 8,000 | <1% | 2,000 | <1% |
| CRE-20 | Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary. | 50,000 | 2% | 42,000 | 3% |
| CRE-21 | Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants. | 275,000 | 11% | 72,000 | 4% |
| CRE-22 | Restore or mitigate contaminated sites. | 300,000 | 12% | 142,000 | 8% |
| CRE-23 | Implement stormwater best management practices in cities and towns. | 65,000 | 3% | 30,000 | 2% |
| | **Total** | 2.5 million | | 1.68 million | |

[1] Appendix B presents more information on how survival improvement targets were developed.

[2] The survival improvement targets are assigned for juvenile salmonids only. Although CRE-14 relates specifically to adult salmonids, the survival numbers for CRE-14 are not included in the 20 percent survival improvement targets for juvenile salmonids. The stream-type survival number is based upon an estimated 17 percent reduction in adult fish mortality applied to 2010 run-size information reported in U.S. Army Corps of Engineers (2010). Some mortality may be occurring as a result of pinniped predation on ocean-type juvenile salmon and steelhead. The extent to which this is occurring has not been established.

# Evaluation of Management Actions: Costs and Schedule

Implementing recovery actions in the estuary will require a long-term commitment by many entities. In Tables 5-2 and 5-5, two approaches were used to portray the potential survival improvements associated with implementing actions. In Table 5-6, each action is broken down into one or more projects that can be considered elements of that action.

For some management actions, the first project involves conducting a study or assembling existing technical information. There are several reasons for this. In some cases, existing information about how to reduce the associated threat to salmonids is limited, and additional study is needed to identify and pilot-test possible actions to determine which ones would be most effective. This is particularly important when funds for implementing management actions are limited. Additionally, conducting a study or assembling technical information involves stakeholders who may have local knowledge about the threat or will be responsible for implementing projects. Lastly, studies and information gathering provide an opportunity to understand the constraints of management actions, to reexamine assumptions about what is and is not possible, and to explore the lengths to which, as a society, we are willing to go to implement actions that will contribute to the recovery of salmon and steelhead in the Columbia River basin. The intent of including studies and information gathering in the management actions, when appropriate, is not to postpone taking on-the-ground action but to ensure that any actions that are taken are truly effective, that stakeholders are involved in the process, and that important dialogue occurs about the value of reducing constraints and implementing management actions as fully as possible, even in situations where implementation is highly constrained.

The recovery plan module does not present a detailed list of projects waiting to be completed in the estuary. This is because in many cases, additional work is needed to develop complex, large-scale projects that will provide maximum benefit, or to work with landowners and other stakeholders to gain their support, or to understand the most effective avenue for implementation.

Table 5-6 provides cost estimates for each of the 23 actions in the estuary recovery plan module and a timeframe for their implementation. Each project in Table 5-6 has a corresponding unit and cost, and the project costs are summed to produce a total cost for each action. The costs identified in this section do not represent a detailed economic analysis; in fact, they are not economic costs in that they have not been discounted across time. Instead, the cost estimates are in constant dollars over a 25-year period. A 25-year implementation period was selected for several reasons. Many of the actions identified in the estuary module include project types that have never been implemented in the estuary, and it will take time to establish or modify programs to implement these projects; some will require new research and monitoring to guide their effective implementation. In addition, a 25-year implementation period will allow time to identify funding sources and build the landowner buy-in and project sponsor capacity needed to implement the 23 actions.

In most cases the costs listed in Table 5-6 are direct, incremental costs, meaning that they are (1) out-of-pocket costs that a public or private interest would pay to initiate and complete a management action, and (2) costs in addition to the baseline costs for existing programs and activities, which may or may not be focused on salmon recovery. This approach is consistent

with NMFS Northwest Regional Office guidance on cost estimates for ESA recovery plans. In some cases, distinctions between baseline and incremental costs are clear. For instance, reducing the abundance of shad (CRE-18) is an action that includes only incremental costs because it is a new action that has yet to be implemented in the estuary. Other actions, such as breaching, lowering, or relocating dikes (CRE-10), have been implemented in the estuary at a relatively modest scale. For such actions, the estuary recovery plan module cost estimate is still entirely incremental in that it identifies an additional level of effort needed to achieve the survival improvement targets identified later in this chapter.

Several of the 23 actions do contain some baseline costs, because in some cases these baseline costs represent a small fraction of the overall implementation cost of the action and it was deemed infeasible to separate out the incremental costs. In these cases, this fact is noted in Table 5-6 under the key assumptions for the individual management action. For example, Caspian tern management (CRE-16) is supported by an existing management plan, and some efforts are already under way to implement the action. The other two examples are managing pikeminnow and other piscivorous fish (CRE-13) and implementing stormwater best management practices (CRE-23). In these examples, programs are in place, but major portions of the estuary recovery plan module action have not been implemented to date. In addition, for one action—adjusting the timing, magnitude, and frequency of hydrosystem flows (CRE-4)—the primary costs are the costs of foregone power generation. Generally, recovery action cost estimates do not include such opportunity costs. We have included an estimate of such costs in this case because otherwise this action would have skewed the cost-effectiveness assessment in Chapter 7 (see Table 7-5) in a way that would preclude constructive dialogue about adjusting flows.

The cost estimates in Table 5-6 were developed by PC Trask & Associates, Inc., and reviewed by the Lower Columbia Fish Recovery Board, the Lower Columbia River Estuary Partnership, and NMFS. In addition, an economist at the NMFS Northwest Fisheries Science Center reviewed Chapter 5 and provided comments (although not a detailed evaluation of the costs). Lower Columbia River Estuary Partnership staff contributed substantively to cost estimates for actions for which the Estuary Partnership has some history of implementation. For example, the Estuary Partnership has funded multiple dike breaches (CRE-10), riparian protection projects (CRE-1), and off-channel protection/restoration projects (CRE-9). In other cases, where possible, experts knowledgeable about implementing similar actions were consulted. For example, staff from the NMFS Northwest Regional Office were consulted to estimate costs for managing pinnipeds (CRE-14).

In still other cases, a coarse estimate was established based on the component projects and assumptions about the feasibility of their implementation. These were generally cases in which the extent of on-the-ground actions could not be determined until certain scientific or technical questions have been answered more definitively through studies or information gathering (see, e.g., CRE-2, CRE-7, CRE-12, CRE-18). In these cases, costs of any assessment work were estimated, and then a coarse-scale, placeholder cost estimate was developed based on assumptions about the magnitude and nature of subsequent projects needed to implement the management action. It is expected that such cost estimates will be refined as more specific projects are defined.

Thus the cost estimates in Table 5-6 attempt to establish a realistic cost for recovery, but the precision with which costs can be estimated at this time is limited, and there is considerable

uncertainty in all the cost estimates. In Chapter 6, some additional costs are identified for research, monitoring, and evaluation activities (see Table 6-7).

The estuary recovery plan module addresses habitat conditions for all Columbia River basin ESUs during a single stage of their life cycle, but many additional management actions—including actions in the tributaries—will be needed to achieve recovery of any particular ESU. Because the management actions in the module are only a subset of all the actions needed for recovery of an ESU, the costs in Table 5-6 do not reflect the total costs to achieve recovery. Total costs for recovery are more appropriately represented in the recovery plans for each ESU, as these plans deal with multiple life stages for a specific ESU.

Each action in Table 5-6 includes a proposed schedule for implementation. The schedule is designed to place projects in a logical order and spread costs over a long period of time when possible. Costs are estimated over a 25-year span, with some projects being implemented once over a relatively short period and others continuing over the entire 25 years.

Other elements contained in Table 5-6 include the association of actions to specific geographical reaches, key assumptions about actions, a list of potential implementers,[6] notes that help explain how costs were developed, and a brief summary of some of the existing programs that address limiting factors identified in this recovery plan module. The summaries of existing programs are not exhaustive and are intended to emphasize that opportunities exist to build on existing programs to improve salmon and steelhead survival in the estuary. The relationship of actions to the eight geographic reaches and the plume helps to define the breadth of the action and may also indicate which jurisdictions may implement actions in the future. Key assumptions relate primarily to implementation and provide insight into the level of effort reflected in the action costs. Notes are specific information that helps clarify a particular unit or cost.

[6] The list of potential implementers is intended only to indicate entities that *may* have a role in implementation and to serve as a guide to begin discussion of implementation roles. It does not imply any budgetary, regulatory, or other responsibility for implementation.

TABLE 5-6
Estimated Cost and Schedule

## Management Action CRE-1:

Protect intact riparian areas in the estuary and restore riparian areas that are degraded.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Educate landowners about the ecosystem benefits of intact riparian areas and the costs of degraded riparian areas.[1] | 20 years @ $50,000/year | $1 million | 2008 - 2028 |
| 2. Encourage and provide incentives for local, state, and Federal regulatory entities to maintain, improve (where needed), and enforce consistent riparian area protections throughout the lower Columbia region.[2] | 10 years @ $500,000/year | $5 million | 2008 - 2018 |
| 3. Actively purchase riparian areas from willing landowners in urban and rural settings when the riparian areas cannot be effectively protected through regulation or voluntary or incentive programs and (1) are intact, or (2) are degraded but have good restoration potential. | Rural: 3,500 acres at $5,000/acre[3]<br>Urban: 100 acres at $75,000/acre | $25 million | 2007 - 2031 |
| 4. Restore and maintain ecological benefits in riparian areas; this includes managing vegetation on dikes and levees to enhance ecological function and adding shoreline/instream complexity for juvenile salmonid refugia. | 28 miles @ $250,000/mile | $ 7 million | 2006 - 2031 |

**Total costs:** $38 million

**Geographical priority:** Reaches A-H and the Lower Willamette reach.

**Key assumptions**: (1) New homes, businesses, and industry will increase with population growth in the basin. (2) Some intact riparian areas are not adequately protected. (3) Protecting intact riparian areas would be cheaper than restoring degraded areas. (4) Some degraded riparian areas could be restored and gain ecological function, with associated downstream benefits. (5) Comprehensive protection and restoration of riparian habitats would occur concurrently with population growth, which will continue at a high rate.

**Existing efforts**: Protection of riparian areas relies heavily on local governments; the content and implementation of their land use plans specifically for shoreline and floodplain protection will be key to this action. Multiple Federal and state resource agencies provide funding for land acquisition and restoration, and multiple entities such as land trusts and watershed councils actively acquire and restore lands in the lower river. The Division of State Lands in Oregon and the Department of Natural Resources in Washington own and/or regulate submerged and submersible lands. The Natural Resource Conversation Service and conservation districts provide technical assistance to private landowners. Where water quality issues (such as toxic or conventional contaminants) are involved, agencies such as Washington's Department of Ecology and Oregon's Department of Environmental Quality may provide additional support.

**Potential implementers:**

- U.S. Army COE
- BPA
- WA Dept. of Fish & Wildlife
- OR Dept. of Fish & Wildlife
- Cities\Counties
- Port districts
- Conservation districts
- Columbia Land Trust
- The Wetlands Conservancy
- The Nature Conservancy
- Ducks Unlimited
- Natl. Fish & Wildlife Foundation
- Tribes
- OR Watershed Enhance. Bd.
- Salmon Recovery Fund. Bd.
- Lower Col. River Est. Partnership
- National Marine Fisheries Service
- Col. River Estuary Study Taskforce
- Utility districts
- Watershed councils

**Notes:**

[1] Projects CRE-1.1 and CRE-9.1 both call for outreach efforts. Outreach efforts for these two actions will be combined in a single outreach program whose costs will be shared.

[2] Projects CRE-1.2 and CRE-9.2 both call for incentives for local, state, and Federal entities to maintain, improve, and enforce regulatory protections. Given their similarities, activities for CRE-1.2 and CRE-9.2 could be coordinated or combined into one effort.

[3] Acreage amounts are 25-year targets that depend on willing sellers and funding.

## Management Action CRE-2:

Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Conduct a reservoir heating study to determine the extent of the issue and identify hydrosystem operational changes (including design) that would reduce effects and/or mitigate downstream temperature issues. | 1 study | $2.5 million | 2007 - 2013 |
| 2. Implement hydrosystem operational changes to reduce temperature effects; if no change is possible, mitigate effects through restoration of tributary riparian areas. | 25 years @ $700,000/year[1] | $17.5 million | 2010 - 2032 |

**Total costs:** $20 million

**Geographical priority:** Reaches A-H and the plume.

**Key assumption**: (1) Either there is potential to alter management practices in the hydrosystem to reduce flow temperatures or a commensurate level of mitigation in tributaries would reduce temperatures in the estuary. (2) If temperatures continue to increase above 19° C, the estuary could become completely lethal for salmonids and other native species.

**Existing efforts:** The U.S. Environmental Protection Agency (EPA) is concerned about water temperature issues in the Columbia and Snake River system and their impacts on ecosystem health, particularly in light of global climate change. Oregon and Washington have listed the Columbia River as impaired for temperature under the Clean Water Act Section 303(d). In 2003, EPA issued a Preliminary Draft Total Maximum Daily Load (TMDL) for the mainstem Columbia River, but the TMDL has not been finalized. EPA plans to work with the states of Oregon and Washington to revisit the TMDL and decide how to address mainstem Columbia River temperature issues.

**Potential implementers:**

- Bonneville Power Administration
- U.S. Army Corps of Engineers
- Utility districts
- Oregon Department of Environmental Quality
- Washington State Department of Ecology

**Notes:**

[1] Assumes that some level of improvement is possible but that the level of possible improvement is likely to be minor because of complexities of the hydrosystem; assumes that mitigation will be needed to offset temperature increases.

## Management Action CRE-3:

Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Explore technical options and develop policy recommendations on instream flows. | 5 years @ $1 million/year | $5 million | 2007 - 2015 |
| 2. Implement instream flow regulations in accordance with the policy recommendations in Project No. 1. | 5 years @ $1 million/year | $5 million | 2015 - 2023 |

**Total costs:** $10 million

**Geographical priority:** Reaches A–H and the plume.

**Key assumptions**: (1) Demand for water for human use will grow as the human population in the basin increases. (2) Additional instream flows in the Columbia River mainstem and tributaries could be established through the efforts of affected parties basinwide. (3) Establishing an instream flow regime would protect flows entering the estuary in the future. (4) An instream flow regime would help develop additional water conservation efforts and guide land use development in concert with water availability. (5) Protecting and/or enhancing estuary instream flows would require coordination with the Columbia River hydrosystem to achieve lasting results.

**Existing efforts:** Resource agencies can request instream flows to support fish and wildlife, water quality, and recreational needs in tributaries entering the estuary. In Oregon, the Department of Environmental Quality, Department of Fish and Wildlife, and Department of Parks & Recreation are authorized to request instream water rights to support their statutory obligations. The Oregon Water Resources Department and Commission review these requests and establish instream water rights. In Washington, the Department of Ecology established instream flows in all of the major Washington tributaries entering the estuary. Tributary flows also are often addressed in the relicensing processes for hydropower facilities regulated by the Federal Energy Regulatory Commission. Over the past decade, many tributary hydropower facilities (e.g., the Cowlitz River Project and the Lewis River Hydroelectric Projects) have been relicensed. Establishing an instream flow regime for the estuary would involve many Federal and state agencies and would require an organizational framework that currently does not exist.

**Potential implementers:**

- States (Washington, Oregon, Idaho, Montana)
- Cities and counties
- Irrigators
- Tributary hydropower utilities
- U.S. Army Corps of Engineers
- Bonneville Power Administration
- U.S. Bureau of Reclamation

## Management Action CRE-4:

Adjust the timing, magnitude, and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Conduct a flood study to determine the risks and feasibility of returning to more normative flows in the estuary. | 2 years @ $500,000/year | $1 million | 2009 - 2010 |
| 2. Conduct a study to determine the habitat effects of increasing the magnitude and frequency of hydrosystem flows (i.e., how much access of river to off-channel habitats would increase). | 3 years @ $500,000/year | $1.5 million | 2009 - 2011 |
| 3. Conduct additional studies to determine the extent of other constraints, including international treaties, systemwide fish management objectives, and power management. | 4 years @ $500,000/year | $2 million | 2010 - 2014 |
| 4. Make policy recommendations to action agencies on flow, taking into consideration beneficial estuary flows, flood management, power generation, irrigation, water supply, fish management, and other interests. | 25 years @ $100,000/year | $2.5 million | 2010 - 2035 |
| 5. Implement modified estuary flow regime annually in concert with other interests, including hydroelectric, flood control, and water withdrawals. | 25 years @ $1.5 million/year[1] | $37.5 million | 2011 - 2036 |

**Total costs:** $44.5 million

**Geographical priority:** All reaches (A-H) and the plume.

**Key assumptions**: (1) Even incremental changes in the magnitude and frequency of hydrosystem flows would improve salmonid habitat opportunity and food inputs, which would have benefits throughout the ecosystem. (2) Studies of flood risk and the effect of flow changes on estuarine habitat would provide data useful in modifying hydrosystem operations to benefit salmonids. (3) Studies of constraints to implementation would identify some obstacles that could be overcome. (4) Small to moderate changes in the magnitude, frequency, and timing of flows would improve sediment transport-related habitat opportunity in the estuary. (5) Increased spring freshets would yield greater sediment transport-related benefits than would other flow modifications.

**Existing efforts:** Large-scale efforts to adjust flows entering the estuary and return hydrology to more historical conditions have not yet begun because of the level of uncertainty regarding potential scenarios for adjusting the timing and volume of flow and the associated habitat benefits. Significant efforts have been undertaken by Bonneville Power Administration, the U.S. Army Corps of Engineers, and the U.S. Bureau of Reclamation to manage the hydrosystem for passage of juvenile salmonids. In addition, flows entering the estuary currently are managed to minimum seasonal flows to protect chum redds in the mainstem below Bonneville Dam.

**Potential implementers:**

- Bonneville Power Administration
- U.S. Army Corps of Engineers
- U.S. Bureau of Reclamation

**Notes:**

[1] Assumes $1.5 million per year cost of decreased hydrosystem generation revenues associated with minor and incremental adjustments to flows; also assumes that the flood risk associated with beneficial estuary flows does not increase significantly. The $1.5 million per year cost is included primarily as an indicator that there would be some foregone revenues even with minor changes in the flow regime. Specific costs will be evaluated during implementation as specific scenarios for modifying flows are developed and considered.

## Management Action CRE-5:

Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Identify the effects of reservoir sediment entrapment on economic and ecological processes; this includes effects on ship channels, turning basins, port access, jetty activities, and habitat availability. | 1 study | $2 million | 2008 - 2011 |
| 2. Develop a regionwide sediment plan for the estuary to address salmonid habitat-forming processes. | 10 years @ $100,000/year | $1 million | 2006 – 2031 |
| 3. Implement projects recommended in the plan to mitigate the effects of sediment entrapment. | 5 projects @ $1 million/project | $5 million | 2010 - 2020 |

**Total costs:** $8 million

**Geographical priority:** Reaches A-H and the plume.

**Key assumptions**: (1) Sediment entrapment in reservoirs will continue. (2) Sediment entrapment has negative effects, both ecologically and economically. (3) The extent of these effects warrants exploration and implementation of potential mitigation measures. (4) Studying potential mitigation measures would identify some actions that would be effective and could be implemented. (5) Synergistic ecological effects may be realized as a result of implementing CRE-5 and CRE-6, which could increase sediment inputs into the estuary (CRE-5) and optimize beneficial uses of dredged materials (CRE-6).

**Existing efforts:** The Lower Columbia Solutions Group, a bi-state organization made up of local, state, and Federal governmental and non-governmental stakeholders, was formed by the governors of Washington and Oregon to address activities related to the disposal of dredged materials in the estuary. Developing a sediment budget is one of the activities of the Lower Columbia Solutions Group; it is likely that this sediment management budget will include the effects of reservoir sediment entrapment.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Bonneville Power Administration

## Management Action CRE-6:

Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Develop a regionwide sediment plan for the estuary and littoral cell. | See CRE-5. | See CRE-5. | See CRE-5. |
| 2. Identify and implement dredged material beneficial use demonstration projects, including the notching and scrape-down of previously disposed materials and placement of new materials for habitat enhancement and/or creation. | 100 acres @ $10,000/ acres | $1 million | 2006 - 2012 |
| 3. Dispose of dredged materials using techniques identified through the demonstration projects and regionwide planning. | 500 acres @ $10,000/acre[1] | $5 million | 2008 - 2033 |

**Total costs:** $6 million

**Geographical priority:** Reaches A, B, C, and G, the Lower Willamette reach, and the plume and nearshore.

**Key assumptions**: (1) Dredging activities will continue or increase over time. (2) Opportunities to beneficially use dredged materials for habitat can be identified. (3) Beneficial use of dredged material would have a positive effect on sediment transport and habitat-forming processes in the estuary, plume, and littoral cell.

**Existing efforts:** Several agencies and organizations are actively engaged in the evaluation of dredged material for ecosystem-based beneficial uses. The Lower Columbia Solutions Group currently is focused on reducing the disposal of dredged materials in open waters off the mouth of the Columbia River in favor of supplementing the nearshore littoral cell with sediments. The Portland District of the U.S. Army Corps of Engineers is exploring tidal wetland development in the estuary based on an assessment of wetlands that have formed accidentally where dredged materials were placed historically. The Port of Portland also is exploring the use of dredged materials for potential development of subtidal habitats.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Port districts
- Cities
- Lower Columbia River Solutions Group
- Oregon Department of Environmental Quality
- Oregon Department of State Lands
- Oregon Department of Fish and Wildlife
- Oregon Department of Land Conservation and Development
- Washington Department of Ecology
- Washington Department of Fish and Wildlife

**Notes:**

[1]Unit cost is funding to pay for activities beyond the minimum required by law, to achieve regional-scale ecosystem benefits.

## Management Action CRE-7:

Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Identify and evaluate dredge operation techniques designed to reduce entrainment and other habitat effects. | 1 project | $500,000 | 2008 - 2010 |
| 2. Initiate demonstration projects designed to test and evaluate dredge operations. | 5 projects @ $200,000/project | $1 million | 2009 - 2012 |
| 3. Implement best management techniques. | 10 years @ $250,000/year[1] | $2.5 million | 2011 – 2036 |
| 4. Study the effects of entrainment of juvenile salmonids from ship ballast water intake. | 1 study @ $250,000 | $250,000 | 2009 – 2011 |
| 5. Implement a demonstration project to evaluate the feasibility of reducing entrainment of juvenile salmonids from ship ballast intake. | 1 project @ $250,000 | 250,000 | 2012 -- 2015 |

**Total costs:** $4.5 million

**Geographical priority:** Reaches A, B, C, D, E, F, G, and the Lower Willamette reach.

**Key assumptions**: (1) Improved best management practices can be identified that would help reduce the impact of dredging. (2) Mitigation activities would help offset changes to the estuary caused by dredging.

**Existing efforts:** The U.S. Army Corps of Engineers and ports in the lower Columbia River have studied the effects of entrainment on aquatic species and have implemented actions to reduce negative effects. Screening and other ship ballast activities to decrease entrainment of juvenile salmonids have been implemented.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Port districts
- Private entities, such as ports and sand and gravel dredgers
- Counties and cities

**Notes:**

[1]This is an estimate of the incremental cost above permitted dredge activities. Cost may vary significantly depending on site-specific conditions.

## Management Action CRE-8:

Remove or modify pilings and pile dikes when removal or modification would benefit juvenile salmonids and improve ecosystem health.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Inventory, assess, and evaluate in-channel pile dikes for their economic value and their negative and positive impacts on the estuary ecosystem; develop working hypotheses for removal or modification. | 1 plan | $250,000 | 2007 - 2009 |
| 2. Implement demonstration projects designed to test working hypotheses and guide future program priorities. | 4 pile dike removal projects @ $125,000/project | $500,000 | 2009 - 2010 |
| 3. Remove or modify priority pilings and pile dikes. | 25 years @ $1 million/year | $25 million | 2008 - 2033 |
| 4. Monitor the physical and biological effects of pile dike removal and/or modification. | 10 years @ $150,000/year | $1.5 million | 2010 - 2020 |

**Total costs:** $27.25 million

**Geographical priority:** Reaches A – H and the Lower Willamette reach.

**Key assumption**: (1) Many pilings, pile dikes, and similar structures could be removed or modified without compromising the shipping channel or protection of property. (2) Over time, the removal or modification of superfluous pile dikes would improve conditions for salmonids and the ecosystem.

**Existing efforts:** This action was incorporated into the 2008 Federal Columbia River Power System Hydropower Biological Opinion (BiOp) Remand as Reasonable and Prudent Alternative 38: Piling and Dike Removal Program. A project team composed of the Lower Columbia River Estuary Partnership, Bonneville Power Administration, and the U.S. Army Corps of Engineers is working to develop a strategic plan to remove, modify, or retain pile structures within the mainstem lower river. (Modification could include adding large wood to make complex habitat, for example.) The program currently is funded at a level of $1 million per year and is expected to be funded through 2018 if the program proves successful in providing benefits to salmonids.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Bonneville Power Administration
- Washington Department of Natural Resources
- Washington Department of Fish and Wildlife
- Oregon Department of Fish and Wildlife
- Oregon Department of Lands
- Lower Columbia River Estuary Partnership
- Counties and cities
- Tribes

## Management Action CRE-9:

Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Educate landowners about the ecosystem benefits of protecting and stewarding intact off-channel areas and the costs of restoring degraded areas.[1] | (See CRE-1.1) | $500,000 | 2008 - 2028 |
| 2. Encourage and provide resources for local, state, and Federal regulatory entities to maintain, improve (where needed), and consistently enforce habitat protections throughout the lower Columbia region.[2] | 10 years @ $500,000 million/year | $5 million | 2008 - 2018 |
| 3. Actively purchase off-channel habitats in urban and rural settings that (1) cannot be effectively protected through regulation, (2) are degraded but have good restoration potential, or (3) are highly degraded but could benefit from long-term restoration solutions.[3] | Rural: 5,000 acres at $3,000/acre<br>Urban:150 acres at $100,000/acre | $30 million | 2007 – 2031 |
| 4. Restore degraded off-channel habitats with high intrinsic potential for increasing habitat quality. | Rural: 6,000 acres at $5,000/acre<br>Urban: 500 acres at $5,000/acre | 32.5 million | 2007 - 2031 |

**Total costs:** $68 million

**Geographical priority:** Reaches A, B, C, and G and the Lower Willamette reach.

**Key assumptions**: (1) Protection opportunities can be increased over the next decade through public awareness, educational, regulatory, and acquisition programs. (2) Protection of off-channel habitats is less expensive than restoration. (3) High-quality off-channel habitats offer benefits to salmonids that cannot be provided in other ways. (4) Protection will be needed to offset increasing threats resulting from human population increases in the estuary and basin. (5) Restoring off-channel habitat function in the estuary is critical to ecosystem processes. (6) Restoring off-channel habitats enhances juvenile salmonid growth by increasing access to food sources and provides refugia from high flows and predation.

**Existing efforts**: Protection of off-channel habitats relies heavily on local governments; the content and implementation of their land use plans specifically for shoreline and floodplain protection will be key to this action. Multiple Federal and state resource agencies provide funding for land acquisition and restoration, and multiple entities such as land trusts and watershed councils actively acquire and restore lands in the lower river. The Division of State Lands in Oregon and the Department of Natural Resources in Washington own and/or regulate submerged and submersible lands. The Natural Resource Conversation Service and conservation districts provide technical assistance to private landowners. Where water quality issues (such as toxic or conventional contaminants) are involved, agencies such as Washington's Department of Ecology and Oregon's Department of Environmental Quality may provide additional support. The Lower Columbia River Estuary Partnership's Habitat Restoration Program largely is directed toward this action, CRE-1, and CRE-10. Organizations such as the Columbia Land Trust and the Columbia River Estuary Study Taskforce are actively involved in off-channel restoration activities.

**Potential implementers:**

- U.S. Army COE
- BPA
- Columbia Land Trust
- The Wetlands Conservancy
- Ducks Unlimited
- Col. River Est. Study Taskforce
- The Nature Conservancy
- Lower Col. River Est. Partnership
- Watershed councils
- OR Watershed Enhancement Bd.
- OR Dept. of Fish and Wildlife
- WA Dept. of Ecology
- Port districts
- Cities
- Conservation districts
- Other special districts
- Tribes

**Notes**:

[1] Projects CRE-1.1 and CRE-9.1 both call for outreach efforts. Outreach efforts for these two actions will be combined in a single outreach program whose costs will be shared.

[2] Projects CRE-1.2 and CRE-9.2 both call for incentives for local, state, and Federal entities to maintain, improve, and enforce regulatory protections. Given their similarities, activities for 1.2 and 9.2 could possibly be coordinated or combined into a single effort.

[3] Assumes purchases are made over a 25-year period with willing sellers.

## Management Action CRE-10:

Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Breach, lower the elevation of, or relocate dikes and levees; create and/or restore tidal marshes, shallow-water habitats, and tide channels. | 5,000 acres[1] @ $10,000/acre | $50 million | 2006 - 2031 |
| 2. Remove tide gates to improve the hydrology between wetlands and the channel and to provide juveniles with physical access to off-channel habitat; use a habitat connectivity index to prioritize projects. | 2,000 acres[1] @ $10,000/acre | $20 million | 2006 - 2031 |
| 3. Upgrade tide gates or perched culverts where (1) no other options exist, (2) upgraded structures can provide appropriate access for juveniles, and (3) ecosystem function would be improved over current conditions. | 1,000 acres[1] @ $5,000/acre | $5 million | 2006 - 2031 |

**Total costs:** $75 million

**Geographical priority:** Reaches A, B, C, E, F, and G and the Lower Willamette reach.

**Key assumptions**: (1) Additional opportunities to restore off-channel habitats can be developed through long-term outreach and improved landowner relationships. (2) Restoration of sites, including elevation restoration, would yield broad-scale ecosystem benefits over time. (3) A habitat connectivity index would help target efforts toward the projects that would provide the greatest benefits. (4) Restoration of highly degraded sites may be necessary to yield long-term benefits.

**Existing efforts**: Multiple Federal and state resource agencies provide funding for restoration activities, including improving hydrologic conditions and access for juvenile salmonids. In the estuary, the U.S. Army Corps of Engineers, Columbia River Estuary Taskforce, and Columbia Land Trust have significant experience breaching dikes or retrofitting tide gates. Other entities, including watershed councils, conservation districts, and private firms, also have experience but sometimes lack sufficient technical and infrastructure capacity. Extensive community outreach and long-term relationship building will be needed to implement this action. The Lower Columbia River Estuary Partnership's Habitat Restoration Program largely is directed toward this action, CRE-1, and CRE-9.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Bonneville Power Administration
- U.S. Fish and Wildlife Service
- Oregon Watershed Enhancement Board
- Oregon Department of Fish and Wildlife
- Columbia Land Trust
- Columbia River Estuary Study Taskforce
- Salmon Recovery Funding Board
- Conservation districts
- Other districts
- Cities
- Counties
- Lower Columbia River Estuary Partnership
- Lower Columbia Fish Recovery Board
- Watershed councils
- Tribes

**Notes:**

[1]Acreage equals amount of affected area. Costs include those associated with protecting other land uses from renovated hydrology (i.e., moving dikes and levees).

## Management Action CRE 11:

Reduce the square footage of over-water structures in the estuary.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Inventory over-water structures and develop a GIS layer with detailed metadata files. | 2 projects @ $150,000/project | $300,000 | 2007 - 2009 |
| 2. Initiate a planning process to evaluate existing and new over-water structures for their economic, ecological, and recreational value. | 2 phases[1] @ $100,000/phase | $200,000 | 2009 - 2013 |
| 3. Remove or modify over-water structures to provide beneficial habitats. | 10 projects @ $500,000/project[2] | $5 million | 2012 - 2037 |
| 4. Establish criteria for new permit applications to consider the cumulative impacts of over-water structures. | 1 project | $300,000 | 2008 - 2010 |

**Total costs:** $5.8 million

**Geographical priority:** Reaches D and G and the Lower Willamette reach.

**Key assumptions**: (1) Over-water structures pose some threat to salmonids. (2) A fair number of over-water structures are no longer in use or have relatively minor value to owners. (3) An inventory of over-water structures would aid in assessing individual structures' economic, ecological, and recreational value.

**Existing efforts:** Over-water structures are regulated by specific sections of the Federal Clean Water Act, state statute, or both. These laws are administered by Federal agencies (U.S. Army Corps of Engineers, U.S. Environmental Protection Agency) or state agencies (Oregon Department of Environmental Quality, Oregon Division of State Lands, Oregon Department of Land Conservation and Development, Washington Department of Ecology, and Washington Department of Natural Resources). The Lower Columbia River Estuary Partnership created a shoreline condition inventory that maps all over-water structures using GIS. Currently, there are no targeted efforts to remove over-water structures in the estuary.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Cities
- Washington Department of Natural Resources
- Oregon Department of Land Conservation and Development
- Oregon Department of State Lands

**Notes:**

[1]The first phase is technical and the second phase is policy.

[2]A project is defined as a set of structures that have been identified for removal; cost is level of effort.

## Management Action CRE-12:

Reduce the effects of vessel wake stranding in the estuary.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Analyze factors contributing to ship wake stranding to determine potential approaches to reducing mortality in locations where juveniles are most vulnerable. Design and implement demonstration projects and monitor their results. | 1 study @ $1 million | $1 million | 2007 - 2010 |
| 2. Implement projects identified in Project No. 1 that are likely to result in the reduction of ship wake stranding events. | 12 projects @ $1 million/project[1] | $12 million | 2011 - 2026 |

**Total costs:** $13 million

**Geographical priority:** Reaches C, D, E, and F.

**Key assumptions:** (1) Vessel wake stranding is a significant issue for ocean- and stream-type salmonids employing the fry life history strategy in the estuary.

**Existing efforts:** The U.S. Army Corps of Engineers initiated a two-phase study on vessel wake stranding associated with the channel deepening project. Phase 1 was completed in 2006 as part of the channel deepening project. Results could be used to design follow-up studies analyzing factors that contribute to ship wake stranding. In addition, in 2008 the Port of Vancouver completed a study designed to estimate the total acres of estuary shoreline (downstream of the port) that may contribute to ship wake stranding.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Columbia River pilots
- Ports
- US Coast Guard
- River and bar pilots

**Notes:**

[1] This is a level-of-effort cost approach that will require information generated in Projects No. 1 and 2.

## Management Action CRE-13:

Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Monitor the abundance levels of pikeminnow, smallmouth bass, walleye, and channel catfish. | 5 monitoring events @ $100,000/event (every 5 years) | $500,000 | 2006 - 2031 |
| 2. Implement actions as necessary to prevent population growth (i.e., modify habitat)[1]; increase the northern pikeminnow bounty program in the estuary. | 25 years @ $500,000/year | $12.5 million | 2006 - 2031 |

**Total costs:** $13 million

**Geographical priority:** Reaches D, E, F, G, and H and the Lower Willamette reach.

**Key assumption**: Management techniques would maintain populations at levels that would maintain or reduce predation impacts to salmonids. A pikeminnow management plan exists and is being implemented. Costs associated with this action are partly covered as a baseline cost. Costs associated with managing other piscivorous fish, including smallmouth bass, walleye, and channel catfish, are entirely incremental costs.

**Existing efforts:** Bonneville Power Administration funds the Northern Pikeminnow Sport Reward Fishery Program whereby anglers receive $4 to $8 for every qualifying northern pikeminnow 9 inches or longer returned to a registration station. Since 1990, more than 3.1 million northern pikeminnow have been removed from the Snake and Columbia rivers as a result of this program. The annual budget for the Northern Pikeminnow Management Program has varied from $2.0 to $6.4 million, with an average of about $3.0 million basinwide.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Washington Department of Fish and Wildlife
- Oregon Department of Fish and Wildlife
- Bonneville Power Administration
- National Marine Fisheries Service

**Notes:**

[1] It is unknown whether projects will be needed to manage warm-water fish. In some cases, there may be warm-water habits close to juvenile habitat, in which case site-specific action would be required.

## Management Action CRE-14:

Identify and implement actions to reduce salmonid predation by pinnipeds.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Expand Federal and state activities at Bonneville Dam to test non-lethal and potentially lethal methods of reducing pinniped populations throughout the estuary. This includes efforts to manage pinnipeds through the Marine Mammal Protection Act. | 5 years @ $500,000/year | $2.5 million | 2007 - 2011 |
| 2. Implement actions likely to reduce pinniped predation on adult salmonids. | 25 years @ $500,000/year[1] | $12.5 million | 2007 - 2032 |

**Total costs:** $15 million

**Geographical priority:** Reaches A-H (especially H).

**Key assumptions**: (1) Mortality from pinnipeds throughout the lower Columbia River may be a larger source of salmonid mortality than previously understood. (2) Further study would clarify the impact of pinniped predation on salmonids; studies by the U.S. Army Corps of Engineers at Bonneville Dam represent a good start on this task. (3) Mortality from pinniped predation could be reduced through non-lethal and lethal methods. (4) The Marine Mammal Protection Act could be modified over time to allow more tools for managing pinnipeds in the estuary. In 2008, NMFS granted authority under Section 120 of the Marine Mammal Protection Act to the states of Oregon, Washington, and Idaho to intentionally take, by lethal methods, individually identifiable California sea lions that prey on Pacific salmon and steelhead at Bonneville Dam (Federal Register 2008).

**Existing efforts:** The National Marine Fisheries Service, Oregon and Washington, the U.S. Army Corps of Engineers, and Bonneville Power Administration have initiated efforts to manage pinnipeds, primarily at Bonneville Dam. As of 2010, efforts included both lethal and non-lethal methods sanctioned under Section 120 of the Marine Mammal Protection Act.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Bonneville Power Administration
- National Marine Fisheries Service
- Columbia River Inter-Tribal Fish Commission
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife

**Notes:**

[1] Units are years; given the constraints to this action, it is likely that ongoing efforts to prevent predation will continue over the next 25 years.

## Management Action CRE-15:

Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of invasive plants.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Increase public awareness of exotic plant species and proper stewardship techniques.[1] | 10 years @ $100,000/year | $1 million | 2008 – 2018 |
| 2. Inventory exotic plant species infestations and develop a GIS layer with detailed metadata files. | 5 phases @ $200,000/phase | $1 million | 2007 – 2012 |
| 3. Implement projects to address infestations on public and private lands. | 10,000 acres @ $1,000/acre | $10 million | 2008 – 2028 |
| 4. Monitor infestation sites. | 20 years @ $25,000/year | $500,000 | 2010 - 2030 |

**Total costs:** $12.5 million

**Geographical priority:** Reaches A-H and the Lower Willamette reach).

**Key assumptions**: (1) Aquatic invasive plants have a negative effect on the estuary ecosystem and affect juvenile salmonids by altering habitat and causing food webs to deteriorate. (2) Additional information is needed on the location, extent, and type of infestations and their effects on the estuary ecosystem. (3) Because introductions of invasive plants can permanently alter the estuary ecosystem, prevention activities are crucial. (4) Education, outreach, and monitoring would help prevent further introductions of invasive plants.

**Existing efforts:** The fish and wildlife departments of Oregon and Washington have management responsibilities for fish and wildlife, including the control of non-indigenous species. The Washington Department of Fish and Wildlife has developed an Aquatic Non-indigenous Species Management Plan. The Pacific States Marine Fisheries Commission promotes interstate communication and facilitates the coordination of aquatic non-indigenous species activities on the West Coast. The Oregon and Washington Sea Grant programs combined to form the Northwest Marine Invasive Species Team to raise the level of awareness about the threats of invasive species. The Invasive Alien Species Executive Order at the Federal level created the Invasive Species Council and directed development of an Invasive Species Management Plan. Multiple Federal and state resource agencies provide funding for restoration projects that remove exotic invasive plants, and entities such as land trusts and watershed councils actively eradicate exotic native plants and plant native species in the lower river. Noxious weed control entities exist in Oregon and Washington to help educate landowners and control invasive plants.

**Potential implementers:**

- U.S. Army Corps of Engineers
- Bonneville Power Administration
- US Fish and Wildlife Service
- State agencies
- Conservation districts
- Noxious weed districts
- Counties
- Cities
- Tribes
- Watershed councils
- Lower Columbia River Estuary Partnership
- The Nature Conservancy
- Landowners

**Notes:**

[1]This project is recommended for upstream mainstem and tributaries, but the costs presented here are for activities in the estuary only. Many exotic plants have established themselves upstream and represent a constant downstream threat to the estuary.

## Management Action CRE-16:

Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Enhance or create tern nesting habitat at alternative sites in Washington, Oregon, and California. | 3 sites @ $1 million/site | $3 million | 2008 - 2012 |
| 2. Reduce tern nesting habitat on East Sand Island from 6 acres to 1 to 1.5 acres. | 1 project @ $4.5 million/project | $4.5 million | 2007 - 2010 |
| 3. Monitor the regional tern population. | 25 years @ $100,000/year | $2.5 million | 2010 - 2035 |

**Total costs:** $10 million

**Geographical priority:** Reaches A and B.

**Key assumption**: Ongoing and new management actions directed to Caspian tern nesting habitat would continue to reduce salmonid mortality from tern predation. A management plan exists and is being implemented. Costs associated with this action are partially covered as a baseline cost.

**Existing efforts:** The U.S. Army Corps of Engineers has recently constructed alternative habitat for Caspian terns outside of the estuary. The Corps also funds studies assessing Caspian tern population levels and predation rates on juvenile salmonids. These studies track terns along the West Coast to determine whether management actions in the lower river result in redistribution of terns elsewhere along the West Coast. A predatory bird Web site (www.birdresearchnw.org) keeps the public and others informed on the status of management plans and research.

**Potential implementers:**

- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife

## Management Action CRE-17:

Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Identify, assess, and evaluate methods of reducing double-crested cormorant abundance numbers. | 1 multiphase study | $1 million | 2007 - 2011 |
| 2. Implement demonstration projects resulting from Project No. 1 (i.e., decoys and audio playback methods). | 5 pilot projects @ $500,000/project | $2.5 million | 2010 - 2015 |
| 3. Implement projects resulting in reduced predation by cormorants.[1] | 10 years @ $700,000/year | $7 million | 2013 - 2023 |

**Total costs:** $10.5 million

**Geographical priority:** Reaches A and B.

**Existing efforts:** The U.S. Army Corps of Engineers funds studies assessing cormorant population levels and predation rates on juvenile salmonids. These studies track cormorants along the West Coast to determine whether management actions in the lower river result in redistribution elsewhere along the West Coast. A predatory bird Web site (www.birdresearchnw.org) keeps the public and others informed on the status of management plans and research.

**Potential implementers:**

- U.S. Army Corps of Engineers
- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife

**Notes:**

[1]This is a level-of-effort cost estimate; efforts to manage cormorants in the estuary are significantly lagging Caspian tern management efforts and will likely be more difficult to implement.

## Management Action CRE-18:

Reduce the abundance of shad in the estuary.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Organize existing technical information about shad and identify data gaps and potential control methods. | 2 phases @ $250,000/phases | $500,000 | 2007 - 2011 |
| 2. Implement demonstration projects to evaluate effective shad management methods. | 4 projects @ $500,000/project | $2 million | 2008 - 2015 |
| 3. Implement shad population management techniques.[1] | 10 years @ $250,000/year | $2.5 million | 2010 - 2015 |
| 4. Monitor and evaluate shad management techniques. | 10 years @ $50,000/year | $500,000 | 2011 - 2021 |

**Total costs:** $5.5 million

**Geographical priority:** Reaches A-H and the Lower Willamette reach.

**Key assumptions**: (1) Shad have negative affects on salmonids in the estuary. (2) Additional research would shed light on how shad affect salmonids and suggest new management techniques. (3) New management techniques would be unlikely to cause significant change.

**Existing efforts:** The U.S. Geological Survey, with funding from Bonneville Power Administration, is studying the presence of American shad in the Columbia River throughout the year, assessing shad diet trends, and PIT tagging up to 1,000 adult pre-spawn shad in the estuary to examine their time of arrival at dams using PIT tag detection technologies in fishways.

**Potential implementers:**

- U.S. Army Corps of Engineers
- U.S. Geological Survey
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife

**Notes:**

[1]This is a level-of-effort cost estimate; currently there are no plans to manage shad abundance levels in the Columbia River.

## Management Action CRE-19:

Prevent new introductions of aquatic invertebrates and reduce the effects of existing infestations.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Assemble existing technical information on introduced aquatic invertebrates in the estuary and develop a plan for managing existing infestations and preventing new infestations. | 2 phases @ $250,000/phase | $500,000 | 2007 - 2010 |
| 2. Implement recommendations from the plan for managing existing infestations and preventing new infestations (Project No. 1, above).[1] | 5 projects @ $500,000/project | $2.5 million | 2008 – 2013 |

**Total costs:** $3 million

**Geographical priority:** Reaches A-H and the Lower Willamette reach.

**Key assumptions**: (1) Ship ballast practices could be improved to help prevent further degradation of the estuary ecosystem. (2) Additional research would help scientists understand the effects of exotic invertebrates on the ecosystem. (3) Because the effects of exotic invertebrates on the ecosystem usually cannot be reversed, it is important to prevent introductions when possible.

**Existing efforts:** Following the direction of the 2007 Oregon Legislature, the Shipping Transport of Aquatic Invasive Species Task Force was convened in 2008 to examine how Oregon can better handle aquatic invasive species coming into the state via shipping activities. The task force compiled a report outlining various aspects of preventing the introduction of aquatic invasive species from shipping-related pathways. The report also recommended steps that the Oregon Department of Environmental Quality, working with other agencies and the shipping industry, can take to bolster efforts to halt the arrival and spread of aquatic invasive species that degrade existing ecosystems and displace native species.

Likewise, the Aquatic Nuisance Species Unit of the Washington Department of Fish and Wildlife (WDFW) has implemented the Washington State ballast water program since 2000. This program receives state funds for program management, vessel report tracking, and vessel inspection efforts. Two vessel inspectors stationed in Puget Sound and the SW/Columbia River regions target high-risk vessels for boarding and ballast sampling. Washington established discharge standards that, as of 2009, had not yet been implemented.

In 2008, the Environmental Protection Agency issued a Vessel General Permit (VGP) as part of the National Pollutant Discharge Elimination System under the Federal Water Pollution Control Act. This permit is intended to regulate discharges resulting from the normal operation of all non-recreational vessels 79 feet or longer. In addition, the ballast water discharge provisions apply to any non-recreational vessel of less than 79 feet and commercial fishing vessels of any size discharging ballast water, and require adoption of best management practices for discharges. Currently, the VGP regulations adopt U.S. Coast Guard ballast water exchange requirements and coastal exchange requirements for domestic voyages along the West Coast but do not include ballast water treatment technology. Under the Clean Water Action Section 401 certification requirements, states can adopt more stringent conditions than the VGP in their certifications if so needed to meet requirements of either the Clean Water Act or state law.

**Potential implementers:**

- Port districts
- Oregon Department of Fish and Wildlife
- Washington Department of Fish and Wildlife
- U.S. Fish and Wildlife Service
- Oregon Department of Agriculture
- Washington State Department of Agriculture
- Portland State University
- Oregon State Marine Board
- Washington State Parks and Recreation Commission
- Oregon Department of Environmental Quality

**Notes:**

[1]This is a level-of-effort cost estimate.

## Management Action CRE-20:

Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Educate landowners, businesses, and other users about practices to reduce usage and the effects of pesticides and fertilizers.[1] | 10 years @ $50,000/year | $500,000 | 2008 - 2018 |
| 2. Implement pesticide, fertilizer, and nutrient best management practices to reduce contaminants entering the estuary. | 10 years @ $1.15 million/year[2] | $11.5 million | 2008 – 2018 |
| 3. Evaluate the adequacy of best management practices and update as needed. | 2 reviews @ $250,000 | $500,000 | 2012 and 2017 |

**Total costs:** $12.5 million

**Geographical priority:** Reaches A-H and the Lower Willamette reach.

**Key assumptions**: (1) Some users of pesticides and fertilizers are not adequately informed about best management practices for these toxic contaminants. (2) Additional benefits to salmonids could be realized through continued efforts by farmers, chemical manufacturers, and regulatory programs to reduce impacts from fertilizers and pesticides. (3) Benefits to salmonids would increase over a relatively long period of time as agricultural practices improve. Several of the projects identified in this action are being implemented and therefore could be considered baseline costs. The costs in this action are considered additive to baseline costs because of the significant effort needed to reduce nutrients and toxic contaminants entering the estuary.

**Existing efforts:** Both Washington and Oregon produce and encourage implementation of best management practices (BMP) manuals to address non-point sources of pollution. In both states, load allocations and reduction strategies are identified through the total maximum daily load (TMDL) process. The Oregon Department of Environmental Quality is now conducting “pesticide stewardship partnerships” in five Oregon watersheds that eventually flow into the Columbia or Willamette rivers. These partnership programs work through outreach with the agricultural community to implement BMPs that will reduce pesticides in rivers and streams. The U.S. Department of Agriculture, through Senate Bill 1010 authorities, is developing plans to ensure BMPs on agricultural lands. The U.S. Environmental Protection Agency convened the Columbia River Basin Toxics Reduction Working Group in 2005 to coordinate monitoring, cleanup, and reporting efforts basinwide. In September 2010, the working group produced the Columbia River Basin Toxics Reduction Action Plan.

**Potential implementers:**

- Washington Department of Agriculture
- Oregon Department of Agriculture
- Cities
- Conservation districts
- U.S. Environmental Protection Agency
- Washington Department of Ecology
- Oregon Department of Environmental Quality
- Lower Columbia River Estuary Partnership
- Natural Resources Conservation Service

**Notes:**

[1] Projects CRE-20.1 and CRE 21.1 both call for outreach efforts. Outreach efforts for these two projects will be combined into a single outreach program whose costs will be shared.

[2] Unit cost includes estimates for the estuary and estuary tributaries only; the action recommends similar upstream activities.

## Management Action CRE-21:

Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Educate the industrial and commercial sectors and the general public on how to reduce the introduction of pollutants into the estuary and its tributaries.[1] | 10 years @ $20,000/year | $200,000 | 2008 - 2028 |
| 2. Identify sources, loads, and pathways of pollutants in the estuary. | 8 years @ $100,000/year | $800,000 | 2010 - 2018 |
| 3. Provide cost-share incentives for National Pollution Discharge Elimination System (NPDES) permit holders to upgrade effluent above their permit requirements. | 10 years @ $1.5 million/year | $15 million | 2010 – 2020 |
| 4. Study and establish threshold treatment standards for pharmaceuticals and other unregulated substance discharges; update existing NPDES permits to reflect the new standards. | 5 years @ $2 million/year | $10 million | 2007 – 2012 |
| 5. Provide grants and low-cost loans to permit holders required to treat effluent to standards established in Project No. 3. | 10 years @ $2 million/year | $20 million | 2012 - 2017 |

**Total costs:** $46 million

**Geographical priority:** Reaches D and G and the Lower Willamette reach.

**Key assumptions**: (1) Non-permitted discharges that currently are occurring would be identified and curtailed. (2) Financial incentives or support would motivate NPDES permit holders to raise their effluent treatment levels above permit requirements. (3) Releases of industrial and commercial pollutants into the estuary would be reduced over time. Several of the projects identified in this action are being implemented and therefore could be considered baseline costs. The costs in this action are considered additive to baseline costs because of the significant effort needed to reduce inputs of pollutants.

**Existing efforts:** In both Oregon and Washington, pollutant load allocations and reduction strategies are identified through the total maximum daily load (TMDL) process. The Oregon Department of Environmental Quality's (DEQ) Water Quality Program is developing a list of key, persistent bioaccumulative toxic contaminants that have a documented effect on human health, wildlife, and aquatic life. The Oregon Legislature has directed DEQ to report on where persistent bioaccumulative toxic contaminants are coming from and options to reduce their discharge. In addition, legislation required Oregon's 52 largest municipal wastewater treatment plants to develop plans by 2011 to reduce priority persistent pollutants through pollution prevention and toxic reduction. Initial monitoring and reduction efforts are to focus on the Willamette River. The U.S. Environmental Protection Agency convened Columbia River Basin Toxics Reduction Working Group in 2005 to coordinate monitoring, cleanup, and reporting efforts basinwide. In September 2010, the working group produced the Columbia River Basin Toxics Reduction Action Plan. The Lower Columbia River Estuary Partnership has created a long-term monitoring strategy that calls for baseline conventional and toxic contaminant data along with data sufficient to assess trends and biological integrity.

**Potential implementers:**

- U.S. Environmental Protection Agency
- Washington Department of Ecology
- Oregon Department of Environmental Quality
- Cities
- Trade groups such as the Oregon Association of Clean Water Agencies that represent wastewater dischargers

**Notes:**

[1] Projects CRE-20.1 and CRE-21.1 both call for outreach efforts. Outreach efforts for these two actions will be combined into a single program whose costs are shared.

## Management Action CRE-22:

Restore or mitigate contaminated sites.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Develop criteria and a process for evaluating contaminated sites to establish their restoration potential. | 1 phase @ $500,000/phase | $500,000 | 2007 - 2017 |
| 2. Develop an integrated multi-state funding strategy to address contamination cleanup in the estuary from non-identifiable upstream sources. | Out-of-Estuary[1] | n/a | 2007 - 2012 |
| 3. Restore those contaminated sites that will yield the greatest ecological and economic benefits. | 20 years @ $3 million/year | $60 million | 2007 - 2027 |

**Total costs:** $60.5 million

**Geographical priority:** Reaches A-H and the Lower Willamette reach.

**Key assumptions**: (1) Monitoring will continue to provide vital data needed to understand the toxic contaminant problem and identify potential solutions. (2) Monitoring will identify hot spots of contamination. (3) Contamination sites will be identified for which responsible parties cannot be determined. (4) Additional analysis would identify contamination sites whose restoration would yield significant ecological and economic benefits. (5) Restoration of contaminated sites would benefit salmonids and the ecosystem over time. (6) The action will include improving the condition of habitats that have been impaired by the contaminants, not just removing pollutants. (7) Clean up will be to levels that support survival and recovery in both the short-term and long-term. Several of the projects identified in this action are being implemented and therefore could be considered baseline costs. The costs in this action are considered additive to baseline costs because of the significant effort needed to address contamination cleanup.

**Existing efforts:** The U.S. Environmental Protection Agency regulates cleanup of contaminated sites under Superfund and other programs, which include monitoring of these sites. The U.S. Environmental Protection Agency convened the Columbia River Basin Toxics Reduction Working Group in 2005 to coordinate monitoring, cleanup, and reporting efforts basinwide. In September 2010, the working group produced the Columbia River Basin Toxics Reduction Action Plan. The Lower Columbia River Estuary Partnership has created a long-term monitoring strategy that calls for baseline conventional and toxic contaminant data along with data sufficient to assess trends and biological integrity. The Estuary Partnership, U.S. Geological Survey, and NMFS completed a 3-year study that compiled and analyzed monthly toxic and conventional pollutant data at five sites, primarily for PAHs, PCBs, estrogenic compounds, flame retardants, current-use pesticides, nutrients, and trace elements, Toxics monitoring of juvenile salmon also was conducted at six sites (for PCBs, PAHs, organochlorine pesticides, and flame retardants) (Lower Columbia River Estuary Partnership 2007). In addition, the Estuary Partnership and NMFS developed three models that describe the role that toxics play in a salmon's life history: a conceptual model of the interactions between contaminants and endangered salmonid species, a contaminant transport and uptake model, and an ecological risk model to provide a quantitative measure of the impact of contaminant exposure on salmonid populations in the Columbia River basin (Spromberg and Johnson 2008, Leary et al. 2005, and Leary et al. 2006).

**Potential implementers:**

- Lower Col. River Est. Partnership
- Col. River Est. Study Taskforce
- Cities
- Conservation districts
- OR Dept. of Env. Quality
- WA State Dept. of Ecology
- Port districts
- U.S. Geological Survey
- Federal regulatory agencies such as the National. Marine Fisheries Service and U.S. Geological Survey

**Notes:**

[1] Cost is considered to be outside the purview of estuary-specific projects.

## Management Action CRE-23:

Implement stormwater best management practices in cities and towns.

| Project | Unit | Cost | Schedule |
|---|---|---|---|
| 1. Monitor stormwater outputs to measure treatment compliance with existing local and state regulations throughout the basin; develop a network of monitoring sites and establish a data repository that includes data collected by permittees. | 10 years @ $200,000/year | $2 million | 2007 - 2015 |
| 2. Establish a fund source for regulatory agencies and local governments to use when insufficient resources are available to (1) access best available science, (2) develop standards beyond requirements, or (3) adequately enforce regulations. | 3 years @ $2 million/year | $6 million | 2009 – 2011 |
| 3. Evaluate the adequacy of best management practices and update as needed. | 3 evaluations @ $500,000 | $1.5 million | 2010 – 2025 |
| 4. Provide incentives for low-impact development practices. | 20 years @ $500,000/year | $10 million | 2010 - 2030 |

**Total costs:** $19.5 million

**Geographical priority**: Reaches D and G and the Lower Willamette reach.

**Key assumptions**: (1) Population growth in the Columbia River basin will continue to influence the hydrology and water quality in the estuary. (2) Stormwater practices could be improved by monitoring and enforcing compliance with existing regulations, making best scientific information available, and developing higher standards. (3) The resulting improvements in hydrology and contaminant exposure in the estuary would occur slowly over time. (4) This action is protective in nature; costs are not associated with retrofitting existing stormwater facilities. Several of the projects identified in this action are being implemented and therefore could be considered baseline costs. The costs in this action are considered additive to baseline costs because of the significant effort needed to address stormwater-related water quality issues.

**Existing efforts:** Both the Washington Department of Ecology and Oregon Department of Environmental Quality produce best management practices manuals to address certain non-point sources. Local governments develop and update land use plans that include stormwater practices and that guide future development. The Lower Columbia River Estuary Partnership has worked with three schools on Schoolyard Stormwater Projects and engaged corporate partners to design and construct stormwater facilities.

**Potential implementers:**

- Cities and counties
- Washington Department of Ecology
- Oregon Department of Environmental Quality
- U.S. Environmental Protection Agency
- Lower Columbia River Estuary Partnership

**Notes:**
This action is recommended for upstream mainstem and tributaries, but the costs presented here are for activities in the estuary only.

Table 5-7 is a summary of costs for the 23 management actions. The total estimated budget for constrained implementation of the actions as described in Table 5-6 approaches is $528.05 million over 25 years. This number contrasts with the $1.1 billion estimated to help restore salmon in Puget Sound tributaries over a 10-year period. Other major ecosystem restoration efforts across the United States, including San Francisco Bay, Chesapeake Bay, the Everglades, and the Louisiana Coast, are estimated to cost several billion dollars apiece.

TABLE 5-7
Summary of Costs of Management Actions

| Number | Action Description | Cost for Constrained Implementation | %* |
|---|---|---|---|
| CRE-01 | Protect intact riparian areas in the estuary and restore riparian areas that are degraded. | $38 million | 7% |
| CRE-02 | Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures. | $20 million | 4% |
| CRE-03 | Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries. | $10 million | 2% |
| CRE-04 | Adjust the timing, magnitude, and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume. | $44.5 million | 8% |
| CRE-05 | Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume. | $8 million | 2% |
| CRE-06 | Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially. | $6 million | 1% |
| CRE-07 | Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary. | $4.5 million | 1% |
| CRE-08 | Remove or modify pilings and pile dikes when removal or modification would benefit juvenile salmonids and improve ecosystem health. | $27.25 million | 5% |
| CRE-09 | Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat. | $68 million | 13% |
| CRE-10 | Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats. | $75 million | 14% |
| CRE-11 | Reduce the square footage of over-water structures in the estuary. | $5.8 million | 1% |
| CRE-12 | Reduce the effects of vessel wake stranding in the estuary. | $13 million | 2% |

| Number | Action Description | Cost for Constrained Implementation | %* |
|---|---|---|---|
| CRE-13 | Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids. | $13 million | 2% |
| CRE-14 | Identify and implement actions to reduce salmonid predation by pinnipeds. | $15 million | 3% |
| CRE-15 | Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of invasive plants. | $12.5 million | 2% |
| CRE-16 | Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island. | $10 million | 2% |
| CRE-17 | Implement projects to reduce double-breasted cormorant habitats and encourage dispersal to other locations. | $10.5 million | 2% |
| CRE-18 | Reduce the abundance of shad in the estuary. | $5.5 million | 1% |
| CRE-19 | Prevent new introductions of aquatic invertebrates and reduce the effects of existing infestations. | $3 million | 1% |
| CRE-20 | Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary. | $12.5 million | 2% |
| CRE-21 | Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants. | $46 million | 9% |
| CRE-22 | Restore or mitigate contaminated sites. | $60.5 million | 11% |
| CRE-23 | Implement stormwater best management practices in cities and towns. | $19.5 million | 4% |
| | **Total** | $528.05 million | |

*Column shows the relative percentage of each action to the total cost. Percentages do not add up to 100 percent because of rounding.

# Summary

The estuary and plume ecosystems are especially vulnerable to threats because these ecosystems are affected by factors across a wide geographic range—from upstream to the estuary itself, and even well out in the Pacific Ocean. A set of actions has been identified to help reduce threats to salmonids in the estuary and plume. Other recovery venues must also address upstream threats to effectively improve degraded habitats in the estuary. This estuary recovery plan module uses survival improvement targets to help estimate the level of effort required and the costs of that effort.

**CHAPTER 6**

# Research, Monitoring, and Evaluation[1]

Research, monitoring, and evaluation (RME) is a critical element of recovery planning for ESA-listed species (Crawford and Rumsey 2010). RME provides essential information for planners, implementers, and managers of recovery programs on the effectiveness of their programs, whether individual actions are improving the performance[2] of listed salmonids, and how limiting factors and threats are affecting salmonids. This chapter describes RME needed to assess juvenile salmonid performance in the estuary and to evaluate the effectiveness of the 23 management actions described in Chapter 5. It also describes existing monitoring plans, programs, and projects that relate to estuary module RME needs and identifies gaps and potential projects to fill those gaps.

Monitoring plans for ESA-listed Columbia Basin salmonids have been or will be drafted for all domain recovery plans in the basin. These monitoring plans address the most basic question in recovery planning: Is the status of the listed population or ESU improving? Estuary RME will address other key questions, such as whether the performance of juvenile salmonids passing through and using the estuary is improving or worsening, and whether the limiting factors that affect the status of a population or ESU within the estuary are changing. Accordingly, estuary RME will complement monitoring for recovery plans for all domains in the Columbia River basin. Additional questions addressed by estuary RME are as follows:

- Are the actions identified in the estuary recovery plan module being implemented correctly, in sufficient scope, and according to schedule?
- What are the effects of estuary management actions on juvenile salmonids and their habitat?
- Are additional actions needed?
- Are there additional or new threats and limiting factors within the estuary beyond those considered in the estuary recovery plan module?
- How will the monitoring data be managed, analyzed, interpreted, and disseminated?
- How will monitoring data be incorporated into management decisions to best allow an adaptive management approach?

Monitoring for this estuary recovery plan module needs to build on ongoing efforts. In particular, *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary*

[1] Catherine Corbett of the Lower Columbia River Estuary Partnership and Gary Johnson of Pacific Northwest National Laboratories provided the principal input to this chapter.

[2] Salmonid performance refers to life history diversity, foraging success, spatial structure, and growth (Bottom et al. 2005).

*Program* (ERME) (Johnson et al. 2008) is an appropriate monitoring plan on which to base the estuary recovery plan module RME. The ERME monitoring plan is important because it formed the basis for estuary RME in the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion (National Marine Fisheries Service 2008a and 2008b), and was carried over into the 2010 FCRPS Supplemental Biological Opinion (National Marine Fisheries Service 2010). In addition, versions of the ERME monitoring plan have been reviewed by the Independent Scientific Review Panel of the Northwest Power and Conservation Council (Independent Scientific Review Panel 2006a and 2006b), along with state and tribal fisheries management agencies. Finally, the ERME monitoring plan was initially developed and refined by an inter-agency estuary/ocean subgroup for Federal RME that included members from the Bonneville Power Administration, the U.S. Army Corps of Engineers, the Lower Columbia River Estuary Partnership, NMFS, and the Pacific Northwest National Laboratory. This chapter borrows greatly from the Johnson et al. (2008) ERME plan.

In addition to the *Research, Monitoring, and Evaluation Program for the Federal Columbia River Estuary* (Johnson et al. 2008), nine other monitoring plans and guidance documents are applicable to a framework for estuary recovery plan module RME (see Table 6-1). The earliest planning document for estuary RME—*Lower Columbia River Estuary Plan, Aquatic Ecosystem Monitoring Strategy for the Lower Columbia River and Information Management Strategy* (Lower Columbia River Estuary Partnership 1998)—outlined a general monitoring strategy that addressed coordination and oversight, data management and quality assurance, conventional and toxic contaminants, habitat, exotic species, and primary production. This document continues to be germane today. More recently, NMFS produced a document for recovery plans called *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead Listed under the Federal Endangered Species Act* (Crawford and Rumsey 2010). This chapter is consistent with the guidance provided in that document, especially regarding the monitoring framework and adaptive management approach.

# RME Framework

The main elements of estuary RME are status and trends monitoring, action effectiveness research, critical uncertainties research, and implementation and compliance monitoring. These elements inform an adaptive management approach that includes synthesis, reporting, and evaluation of monitoring data and use of results to modify management actions and monitoring programs. The main elements of the estuary RME are described below.

## Status and Trends Monitoring

The overall objective of status and trends monitoring in the estuary is to determine the status of ESA-listed salmonids, determine environmental conditions that are ecologically significant to listed species, and track how the status changes over time. The results of status and trends monitoring should provide information on ambient environmental conditions and insight into the cumulative effects of existing and new management actions and anthropogenic impacts as they occur.

TABLE 6-1
Monitoring Plans Applicable to Estuary RME

| Title | Lead Agency(s) | Description | Application |
|---|---|---|---|
| *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead Listed under the Federal Endangered Species Act* (Crawford and Rumsey 2010) | NMFS | This document provides general guidance for monitoring and evaluation within an adaptive management framework for recovery plans for ESA-listed salmonids in the Pacific Northwest. | Estuary recovery plan module RME used the monitoring elements and adaptive management approach espoused in this work. |
| *Lower Columbia River Estuary Plan, Volume 2: Aquatic Ecosystem Monitoring Strategy* (Lower Columbia River Estuary Partnership 1998) | Estuary Partnership | The *Monitoring Strategy* makes specific recommendations for monitoring oversight, data management, and monitoring and research on pollutants, toxics, habitat, exotic species, and primary production. | Many of the recommendations in this strategy pertain to the management actions in the estuary recovery plan module and, thus, were inherently applied to module RME. |
| *Columbia River Basin Research Plan* (Northwest Power and Conservation Council 2006a) | NPCC | This plan identifies key uncertainties that, if resolved, would support actions to conserve and recover fish and wildlife populations addressed in the BPA/NPCC's Fish and Wildlife Program. There are three uncertainties listed for the estuary, one of the plan's focal areas. | Research called for in this plan informs many of the management actions in the estuary recovery plan module. |
| *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program* (Johnson et al. 2008) | BPA/ NMFS/ NPCC/USACE | This plan for RME in the tidally influenced area, from Bonneville Dam to the ocean, including the plume, has specific goals and objectives, a conceptual ecosystem model, monitored indicators, method and protocols, and an action plan. This is a working document that is periodically updated based on new knowledge and program maturation. | Estuary recovery plan module RME relied on applicable content in this plan. |
| *Guidance for Developing Monitoring and Evaluation as a Program Element of the Fish and Wildlife Program* (Northwest Power and Conservation Council 2006b) | NPCC | This report concerns monitoring and evaluation for the Fish and Wildlife Program. It develops monitoring and evaluation guidance at two levels: Council policy-makers and project implementers. The Council's Fish and Wildlife Program was last approved in 2009. | The guidance in this report, although general, is basic to monitoring and evaluation planning and was applied as appropriate in estuary recovery plan module RME. |
| *Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan* (Lower Columbia Fish Recovery Board 2010) | LCFRB | The plan includes an extensive section on monitoring and research designed to evaluate biological status of listed salmon and steelhead, tributary habitat status, implementation compliance, and action effectiveness. | Applicability to estuary recovery plan module RME is limited because the material focuses on tributary watersheds of the lower Col. R. and estuary. |
| *Lower Columbia River Conservation and Recovery Plan for Oregon Populations of Salmon and Steelhead* (ODFW 2010) | ODFW | This plan includes an extensive section on monitoring and research designed to evaluate biological status of listed salmon and steelhead, status of tributary habitat and other limiting factors, implementation compliance, and action effectiveness. | Applicability to estuary recovery plan module RME is limited because the material focuses on tributary watersheds of the lower Col. R. and estuary |
| *FCRPS 2008 Biological Opinion and 2010 Supplemental Biological Opinion* (NMFS 2008 and NMFS 2010) | NMFS | The Reasonable and Prudent Alternative in the 2008 BiOp includes estuary RME actions and subactions. These were incorporated by reference into the 2010 Supplemental BiOp. | There is some overlap between the management actions in the estuary recovery plan module and the RPAs in the Biological Opinions. As appropriate, RME from the Biological Opinions was incorporated into estuary recovery plan module RME. |

| Title | Lead Agency(s) | Description | Application |
|---|---|---|---|
| *Supplement to the Mainstem Lower Columbia River and Estuary Subbasin Plan* (Lower Columbia River Estuary Partnership 2004b) | Estuary Partnership | This supplement clarifies and provides additional details about the key elements in the subbasin plan for the estuary. It does not, however, explicitly develop an RME plan. | The supplement supports estuary RME, although specific recommendations are not provided. |
| *Upper Columbia Monitoring and Evaluation Plan* (Upper Columbia Technical Recovery Team 2007) | Upper Columbia Technical Recovery Team | This working draft provides a comprehensive plan for tributary RME. Many of the monitoring concepts are consistent with those used in the estuary. | Estuary recovery plan module RME used the monitoring guidance categories in this plan. |

The U.S. Environmental Protection Agency (2000) developed 15 guidelines for developing environmental indicators that provide this type of information, including the following:

- Relevance to the assessment. Monitored indicators should be responsive to an identified question and provide information useful for management decisions.
- Linkage to management action. An indicator is useful only if it can provide adequate information to support management decisions or quantify the success of past decisions.
- Temporal variability across years. Although an indicator may show inter-annual variability, the indicator should reflect true trends in environmental conditions for the assessment question. To determine variability across years, monitoring must proceed for several years at relatively stable sites. Having a long time series of data is particularly important in the estuary, where the benefits of habitat restoration could be masked by salmonid population changes that are due to variable ocean conditions.

Examples of indicators include direct measurements (such as nutrient concentrations), indices, and multimetrics (fish assemblage, for example) (U.S. Environmental Protection Agency 2000).

There are two major objectives for status and trends monitoring in the estuary: (1) assess habitat conditions and limiting factors and threats as described in the estuary recovery plan module and (2) assess juvenile salmonid performance in the estuary. Johnson et al. (2008) list the following status and trends objectives for the estuary:

1. Status and Trends Monitoring (STM): Habitat Conditions – Determine the status and trends of monitored indicators for estuary/ocean conditions that are ecologically significant to listed salmonids in the lower river, estuary, plume, and nearshore ocean.

    STM 1. Map bathymetry and topography of the estuary as needed for RME.

STM 2. Establish a hierarchical habitat classification system based on hydrogeomorphology, ground-truth it with vegetation cover monitoring data, and map existing habitats.

STM 3. Develop an index of habitat connectivity and apply it to each of the eight reaches of the study area.

STM 4. Monitor habitat conditions periodically, including water surface elevation, vegetation cover, plant community structure, substrate characteristics, dissolved oxygen, temperature, conductivity, and primary and secondary production at representative locations in the estuary and plume.

2. Status and Trends Monitoring: Juvenile Salmonid Performance – Determine the status and trends of monitored indicators for juvenile salmonid performance in the estuary and plume.

   STM 5. Evaluate migration characteristics, including juvenile salmonid abundance, residence times, growth rates, diets, and prey resources at representative locations in the estuary and plume to understand habitat usage and relative ecological importance of various habitats to juvenile salmonids.

   STM 6. Monitor and evaluate juvenile salmonid survival from Bonneville Dam through the estuary into the plume.

   STM 7. Develop an index and monitor and evaluate life history diversity of juvenile salmonid populations at representative locations in the estuary.

   STM 8. Monitor and evaluate temporal and spatial species composition, abundance, and foraging rates of juvenile salmonid predators at representative locations in the estuary and plume.

Johnson et al. (2008) also provide guidance on potential indicators that can be monitored to provide information relevant to these objectives. Additional information about status and trends monitoring objectives can be found in the *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program* (Johnson et al. 2008).

## Action Effectiveness Research

The overall objective of action effectiveness research in the estuary is to provide information about the effects of management actions. Using a representative set of management actions, such as specific types of habitat restoration, researchers monitor a suite of variables to evaluate the effects of individual actions on juvenile salmon and their estuarine habitats and provide feedback on potential methods for improving techniques, locations, or other aspects of the action. Action effectiveness research usually involves project-scale monitoring of site-specific conditions to determine whether implemented actions were effective in creating the desired change and whether project- or program-specific performance goals were met. This type of monitoring also can include long-term post-project implementation monitoring to see whether the actions continue to function as they were designed or intended. In some cases the information needed for action effectiveness monitoring may be provided by status and trends monitoring, but action effectiveness research generally requires focused evaluations of more specific parameters directly associated with actions.

The intent of action effectiveness research (AER) is to use quantitative studies to demonstrate how habitat restoration actions affect factors controlling ecosystem structures and processes at site and landscape scales and produce changes in juvenile salmonid performance. The following sub-objectives are from Johnson et al. (2008):

Using a representative set of projects, monitor and evaluate the effects of habitat restoration actions in the estuary, as follows:

> AER 1. Develop a limited number of reference sites for typical habitats, e.g., tidal swamp, marsh, island, and tributary delta, to use in action effectiveness evaluations.
>
> AER 2. Evaluate the effects of selected individual habitat restoration actions at project sites relative to reference sites and evaluate post-restoration trajectories based on project-specific goals and objectives. ("Effectiveness Monitoring")
>
> AER 3. Develop and implement a methodology to estimate the cumulative effects of habitat conservation and restoration projects in terms of cause-and-effect relationships between ecosystem controlling factors, structures, and processes affecting salmon habitats and performance. ("Validation Monitoring")

## Critical Uncertainties Research

The overall objective of critical uncertainties research in the estuary is to investigate uncertainties in the state-of-the-science that are pivotal to understanding fish performance within the estuary. Uncertainties include cause-and-effect relationships among fish, limiting factors, threats, and activities meant to protect or enhance fish performance. The following three critical uncertainties were identified as particularly relevant to this module:

- Extent of density dependence mortality in the estuary and the role of large releases of hatchery fish in density dependence
- Effects of climate cycles and global warming on salmonid performance in the estuary
- The amount of increased juvenile survival in the estuary that could reasonably be expected if all 23 management actions in the module were implemented, and the proportion of that increased survival that could be attributed to each action

Critical uncertainties were also identified in Johnson et al. (2008). The following sub-objectives pertain to critical uncertainties research (CUR):

> CUR 1. Continue work to define the ecological importance of the tidal freshwater, estuary, plume and nearshore ocean environments to the viability and recovery of listed salmonid populations in the Columbia Basin.
>
> CUR 2. Continue work to define the causal mechanisms and migration/behavior characteristics affecting survival of juvenile salmon during their first weeks in the ocean.
>
> CUR 3. Investigate the importance of the early life history of salmon populations in tidal freshwater of the lower Columbia River.

CUR 4. Investigate the effects of hatchery fish on wild (naturally produced) fish in the estuary.

CUR 5. Understand the wetting and drying of the floodplain habitats caused by complex hydrodynamic interactions of tides, mainstem and tributary flows, and the effect of the FCRPS on river conditions.

By testing assumptions related to these and other critical uncertainties, recovery program planners, implementers, and managers can refine the foundation, implementation, and effectiveness of the management actions described in Chapter 5 to incorporate the best available science as it becomes accessible.

## Implementation and Compliance Monitoring

The overall objective of implementation and compliance monitoring is to determine whether projects that address management actions are being implemented correctly, in sufficient quantities, and according to schedule. This monitoring is important for evaluating whether recovery programs are meeting objectives and performance measures, such as the number of estuary habitat acres conserved or restored annually. Objectives and performance measures for implementation and compliance monitoring are specific to the programs they evaluate; thus, in this case, performance measures and the resulting implementation monitoring would need to reflect targets derived from the 23 management actions in Chapter 5. Johnson et al. (2008) identified the following implementation and compliance monitoring (ICM) objectives:

ICM 1. Determine whether restoration projects were carried out as planned, i.e., whether specified project criteria were met ("Implementation Monitoring").

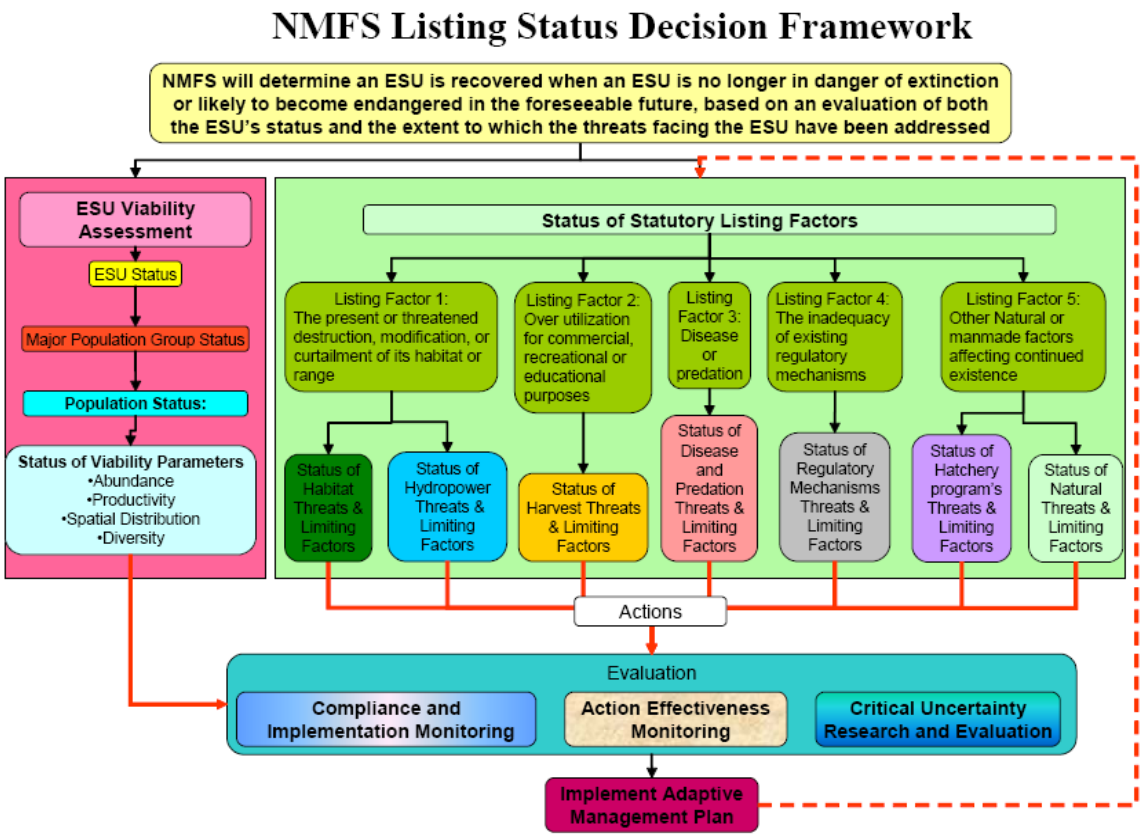
ICM 2. Total the amount of estuary habitat conserved and restored annually by habitat type.

## Adaptive Management Approach

Estuary recovery plan module RME will employ an adaptive management approach. Adaptive management is the process of adjusting management actions based on new information. Management actions must be taken in an adaptive, experimental manner because ecosystems are inherently variable and highly complex (Independent Scientific Review Panel 2007). The process works by coupling decision making with the collection and evaluation of performance data and offering an explicit process through which alternative strategies to achieve the same ends can be proposed, prioritized, and implemented when necessary (Crawford and Rumsey 2010).

Figure 6-1 shows the role of RME and adaptive management in NMFS decisions regarding listing salmonids under the Endangered Species Act. The estuary recovery plan module addresses limiting factors and threats, which led to the management actions listed in Chapter 5. The RME described in this chapter will result in new information for use in evaluating the status of statutory listing factors and limiting factors and adjusting management actions as needed.

FIGURE 6-1
NMFS Listing Status Decision Framework (Crawford and Rumsey 2010)




The adaptive management approach in the estuary recovery plan module is intended to achieve effective management actions in the Columbia River estuary ecosystem. For the estuary recovery plan module, adaptive management entails the following:

- Management actions
- Research, monitoring, and evaluation actions
- Coordination and implementation
- Data and information management
- Synthesis, reporting, and evaluation
- Decisions

Estuary-scale adaptive management will benefit from adaptive management planning by individual organizations (such as the Lower Columbia River Estuary Partnership and the U.S. Army Corps of Engineers) for their habitat restoration projects and programs (see Thom et al. 2007).

## Coordination

Coordination is critical in implementing RME for the Columbia River estuary, where multiple entities collect data for numerous individual projects with various objectives and potentially different monitoring protocols. Successful implementation and

evaluation of estuary recovery plan module RME will require that ongoing and future RME efforts be coordinated and carried out within an adaptive management framework. An estuary RME information-sharing forum should be established that includes technical representatives of Federal, state, and local government agencies; the Lower Columbia River Estuary Partnership; and other entities involved in research, monitoring, and implementation of recovery actions. This forum would be a valuable mechanism for fulfilling the coordination need and would complement corresponding groups of policy representatives responsible for implementation.

## Data and Information Management

Data and other information pertinent to estuary RME are collected by many parties for a wide variety of applications. Data analysis and management are performed at a project and sometimes agency level, but not often at the estuary-wide level. It is neither desirable nor feasible to centrally manage or analyze all data within the Columbia River estuary. However, data should be managed so that synthesis and evaluation occurs through a coordinated, communal information network that includes the following elements:[3]

- Incorporation of data produced by existing programs and information systems to avoid duplication of effort.
- Integration with other basinwide and regional RME groups, including the Pacific Northwest Aquatic Monitoring Partnership.
- Regular written project-level reporting by RME partners within a coordinated system for peer review of project plans and reports.
- Periodic estuary RME workshops to present new data, discuss findings, and exchange information on future plans.
- A system for tracking implementation of RME projects throughout the estuary.
- Establishment of a central, Web-accessible repository and library for estuary data and references.
- Guidelines for metadata standards to facilitate data exchange and application.
- Centrally facilitated program-level review for comprehensive synthesis and evaluation of pertinent information relative to the goals and objectives of this plan.
- Periodic program-level summary reports.
- Communication and information exchange with other West Coast estuary and adaptive management programs, such as the Puget Sound Partnership.
- Consistent participation and funding commitments by partners.

A data management program for the estuary should build on existing efforts, such as the Lower Columbia River Estuary Partnership's monitoring and data management activities. The Estuary Partnership's science work group (and board of directors)

[3] Adapted from Johnson et al. (2008) and Lower Columbia River Estuary Partnership (2004a).

includes technical representatives of Federal, state, and local government agencies and other entities involved in restoration, monitoring, and implementation of recovery programs. This work group complements corresponding groups of policy representatives.

### Synthesis, Reporting, and Evaluation

The information from status and trends monitoring, action effectiveness research, critical uncertainties research, and implementation and compliance monitoring should be synthesized and integrated in periodic reports for decision makers and other interested parties. The intent is to "roll up" project-specific data into program-level information. Annual reporting at the project level should be a key mechanism for data dissemination; biennial reporting at the program level should be key to disseminating results of evaluations. The estuary RME information-sharing forum described above could guide the synthesis and roll-up in the biennial report. In an adaptive management process, program evaluation includes adjusting program objectives and methodologies based on new information. As Noon (2003) stated, monitoring programs "must be constantly revisited and revised as scientific knowledge is acquired." Procedures should be established that link decision makers to estuary RME monitoring overseers and data managers. To conclude, Johnson et al. (2008) recommended the following synthesis and evaluation activities:

> SE 1. Upload, compile, manage, and disseminate project-level data at the Estuary Program level.
>
> SE 2. Synthesize the data and periodically report it to the region.
>
> SE 3. Use the synthesized data to evaluate the Estuary Program and refine the estuary RME effort as necessary.

## Existing Programs and Projects and Additional Monitoring Needs

Activities conducted as part of the ERME program (Johnson et al. 2008) and other efforts do not fully address all of the monitoring needs associated with the 23 management actions identified in the module. The following sections describe (1) existing monitoring programs and projects and their applicability to the 23 management actions identified in the module; (2) gaps between existing monitoring efforts and needed monitoring for the management actions; (3) additional monitoring activities to fill those gaps and ensure monitoring to support all of the 23 management actions; (4) recommended indicators and protocols; and (5) estimated costs of estuary module RME.

### Existing Programs and Projects

Estuary recovery plan module RME will take advantage of ongoing monitoring programs and the projects implemented within them wherever possible to avoid duplication of effort. At least 21 ongoing programs include projects that address aspects of research and monitoring in the estuary (see Table 6-2). The largest RME programs are the Columbia Basin Fish and Wildlife Program, which is funded by Bonneville Power Administration via the Northwest Power and Conservation Council, and the

Anadromous Fish Evaluation Program, which is funded by the U.S. Army Corps of Engineers. These two programs address estuary RME explicitly. The other programs exist for purposes other than estuary RME, but are applicable in a limited fashion.

The research and monitoring effort in the estuary includes at least 42 projects (see Table 6-3). This project list was derived from data in Johnson et al. (2008), the Estuary Partnership's RME inventory (conducted by K. Jones), and the Pacific Northwest Aquatic Monitoring Partnership's RME Project Inventory (database provided by M. Banach, Pacific States Marine Fisheries Commission). The projects include status and trends monitoring, action effectiveness research, and critical uncertainties research.

### RME Needs, Existing Project Coverage, and Recommended Projects

Table 6-4 identifies monitoring needs for each of the 23 management actions in the estuary recovery plan module (see Tables 5-2 and 5-6), lists existing projects and programs that help address the needs, and identifies gaps. Table 6-5 identifies potential new projects to fill the RME gaps identified in Table 6-4. In addition, all of the management actions will require implementation and compliance monitoring.

### Monitoring Recommendations

Table 6-6 provides recommendations specific to each need identified in Table 6-4. Recommendations include sampling design, spatial and temporal scale, measured variables, measurement protocols, derived variables, analysis, possible funding entities, and potential entities for implementation and coordination. Many of the measured variables and measurement protocols were obtained from Johnson et al. (2008). Specific monitoring methods will developed on a project basis. Habitat restoration monitoring protocols for the Columbia River estuary have been developed and disseminated in Roegner et al. (2009) (Table 6-3, Project J15). Mention of possible funding entities in Table 6-6 does not imply a funding commitment of any kind.

## Estimated Costs

Table 6-7 presents estimates of costs and implementation schedules for estuary recovery plan module RME. These cost estimates were developed by Gary Johnson of Pacific Northwest National Laboratories, Catherine Corbett of the Lower Columbia River Estuary Partnership, and Phil Trask of PC Trask & Associates, Inc., by researching existing programs and estimates. The costs identified in this section do not represent a detailed economic analysis; in fact, they are not economic costs, in that they have not been discounted across time. Instead, the cost estimates are in constant dollars over a 25-year period. As mentioned previously, some module actions included specific RME projects and associated cost estimates (see Table 5-6). In those cases, Table 5-6 is referenced. Other costs in Table 6-7 ($64.1 million) were estimated by evaluating the monitoring needs in Table 6-6. The total cost of the RME projects identified in the estuary recovery plan module is $85.1 million.

## Summary

Monitoring, research, and evaluation elements identified in *Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead Listed under the Federal Endangered*

*Species Act* (Crawford and Rumsey 2010) and *Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program* (Johnson et al. 2008) provide a consistent methodology that supports the RME detailed in this chapter for the estuary recovery plan module. As management actions identified in the module are implemented, it will be important that monitoring and research data are returned to the managers of the recovery effort to determine whether the management actions in the estuary recovery plan module are achieving the desired results.

TABLE 6-2
Ongoing Monitoring Programs Applicable to Estuary RME (as of July 2009). *The program "ID" number was invented for the purpose of this module to provide linkages to Table 6-3.*

| ID | Program | Lead Entity | Description | More Information |
|---|---|---|---|---|
| P1 | National Stream Quality Accounting Network (reported in National Streamflow Information Program) | USGS (and OHSU) | Monitoring at Beaver Terminal (RM54); includes water quality and discharge measurements. Water quality components enhanced by OHSU collaboration since summer 2009. | NASQAN: http://water.usgs.gov/nasqan/<br>Water quality (as of summer 2009): http://columbia.loboviz.com/loboviz/<br>Columbia River Factsheet: http://water.usgs.gov/ nasqan/progdocs/factsheets/ clmbfact/clmbfact.html |
| P2 | National Water-Quality Assessment Program | USGS | Routine water quality monitoring nationwide; it includes the Willamette basin, but not the estuary. | NAWQA: http://water.usgs. gov/nawqa/<br>Willamette page: http://or.water.usgs.gov/ projs_dir/pn366/ nawqa.html |
| P3 | Columbia Basin Fish and Wildlife Program | BPA/ NPCC | Contains a measure addressing the question, "Is the Columbia River estuary improving or deteriorating relative to desired conditions?" BPA/NPCC implements estuary RME projects here. | http://www. nwcouncil.org/ library/2000/ |
| P4 | Columbia River Channel Improvements Project | USACE | Monitoring occurs as required for ESA concerns. | https://www.nwp. usace.army.mil/ issues/crcip/ |
| P5 | Mouth of the Columbia River Project | USACE/ Ports | Monitoring occurs as required for ESA concerns. | https://www.nwp. usace.army.mil/op/n/ projects/ |
| P6 | Anadromous Fish Evaluation Program (AFEP) | USACE | Implements the Columbia River Fish Mitigation Project designed to improve survival through the hydrosystem. The USACE does estuary research in AFEP. | https://www.nwd. usace.army.mil/ps/ |
| P7 | NOAA General Funds Program | NOAA | Provides funds for specific estuary/ocean research projects by NOAA. | Unknown |
| P8 | Oregon Dept. of Environmental Quality/106/General Funds | ODEQ | Focus is on Willamette, including its confluence with the Columbia River. | http://www.deq.state. or.us/lab/ wqm/watershed.htm |
| P9 | Total Dissolved Gas Monitoring Program | USACE/ USGS | Routine monitoring. | USGS: http://or.water.usgs.gov/ projs_dir/pn307.tdg/<br>USACE: http:// 137.161.202.92/TMT/ WQ/2001/ MonitorPlan/ tdgmgt01.pdf |
| P10 | Washington Dept. of Ecology Ambient Monitoring Program | WDE | Usually includes at least one mainstem site, in addition to tributary water quality monitoring. | Monitoring Home: http://www.ecy.wa.gov/ programs/eap/ fw_riv/rv_main.html |

| ID | Program | Lead Entity | Description | More Information |
|---|---|---|---|---|
| P11 | Water Resources Development Act – Ecosystem Restoration Programs | USACE | USACE conducts monitoring of specific restoration actions conducted under these authorities; monitoring maximum cost is 3% total project cost. | https://www.nwp. usace.army.mil/pm/lcr/ |
| P12 | Lower Columbia River Ecosystem Restoration General Investigations Feasibility Study (GI Study) | USACE | The purpose of the GI Study is to "investigate and recommend appropriate solutions to accomplish ecosystem restoration in the lower Columbia River and estuary, including wetland/riparian habitat restoration, stream and fisheries improvement, water quality, and water-related infrastructure improvements." | https://www.nwp.usace.army.mil/ pm/cr/envres.asp |
| P13 | Portland Harbor Superfund Assessment Program | EPA | Implements cleanup at the Superfund site in Portland harbor. | EPA: http://yosemite.epa.gov/R10/ CLEANUP.NSF/sites/ ptldharbor |
| P14 | Estuary Partnership Ecosystem, Action Effectiveness and Pile Structure Monitoring Programs | Estuary Partnership | Implements an Ecosystem Condition Status and Trends Monitoring Strategy, Restoration Actions Effectiveness Research and Pile Structure Modification action effectiveness research and critical uncertainties. Funding by BPA/NPCC, EPA, NOAA, and others. | http://www.lcrep.org |
| P15 | NOAA Tides and Currents | NOAA | Geodetic monitoring | http://tidesandcurrents.noaa.gov/ |
| P16 | Surface Water Data Collection Program | USGS | Water quality monitoring (at Beaver Terminal combined with OHSU as of summer 2009) | http://columbia.loboviz.com/loboviz/ |
| P17 | Volunteer Water Quality Monitoring Program | Will. River Keeper | Volunteer water quality monitoring | |
| P18 | Zebra Mussel Monitoring Program | Portland State Univ. | Monitoring of zebra mussels, an invasive species | Contact: Steven Wells |
| P19 | National Fish and Wildlife Foundation, Columbia River Estuarine Coastal Fund | National Fish and Wildlife Foundation (NFWF) | The Columbia River Estuarine Coastal Fund was established in 2004 to receive community service payments ordered by court settlements resulting from violations of Federal pollution laws. | http://www.nfwf.org/ |
| P20 | Ship-wake program | Port of Vancouver/NOAA | Spatial analysis of beach susceptibility for stranding of juvenile salmonids by ship wakes | |
| P21 | (Untitled) | City of Portland | Monitoring of project effectiveness, fish and wildlife, water quality, and stormwater within Portland's waterways, including the lower Willamette River. The City is in the process of revising its monitoring approach, modeling the design on EPA's Environmental Monitoring and Assessment Program. | http://www.portlandonline.com/bes/ Kaitlin.Lovell@bes.ci.portland.or.us |

TABLE 6-3
Ongoing Projects Addressing Estuary RME (as of July 2009)
*The project "ID" number (e.g., J4) was invented for the purpose of this module to provide linkages to Table 6-4. Project numbers (e.g., 2000-012-00) are specific to the respective program. Program numbers (e.g., P3) correspond to the program ID numbers in Table 6-2.*

| ID | Title | Project No. | Program | Monitoring Entity |
|---|---|---|---|---|
| J1 | ODEQ Ambient Water Quality Monitoring | Unknown | P8 | OR Dept. of Env. Quality |
| J2 | WDOE Ambient Water Quality Monitoring | Unknown | P10 | WA Dept. of Ecology |
| J3 | USGS Discharge and Water Quality Monitoring | Unknown | P1 | USGS |
| J4 | Ives Is. Chum Salmon Monitoring | 2000-012-00 | P3 | USFWS |
| J5 | Lower Columbia River and Estuary Ecosystem Monitoring Project | 2003-007-00 | P14 + P3 | Estuary Partnership/ NOAA/PNNL/UW/USGS |
| J6 | Total Dissolved Gas Monitoring | PNAMP#409 | P9 | USGS |
| J7 | Avian Predation on Juvenile Salmonids | 1997-024-00 | P3 | OSU |
| J8 | Tenasillahe Is. Monitoring | Unknown | P11 | USFWS |
| J9 | Canada-US Shelf Salmon Survival Study | 2003-009-00 | P3 | DFO |
| J10 | Life History, Habitat Connectivity, and Survival Benefits of Restoration | EST-P-09-01 | P6 | PNNL/UW |
| J11 | Estimation of Salmon Survival Using Miniaturized Acoustic Tags | EST-P-02-01 | P6 | NMFS/ PNNL |
| J12 | Tidal Fluvial Habitats and Juvenile Salmon – Current and Historical Linkages | EST-P-10-01 | P6 | NMFS |
| J13 | Sampling PIT Tagged Juvenile Salmonids Migrating in the Estuary | BPS-W-00-11 | P6 | NMFS |
| J14 | Survival and Growth of Juvenile Salmonids in the Columbia River Plume | 1998-014-00 | P3 | NMFS |
| J15 | Evaluation of Cumulative Ecosystem Response to Restoration | EST-P-02-04 | P6 | PNNL/ NMFS/ CREST |
| J16 | Action effectiveness research on habitat restoration projects | EST-P-09-02 | P6 | USFWS |
| J17 | Historic Habitat Opportunities and Food-Web Linkages of Juvenile Salmon | 2003-010-00 | P3 | NMFS/ OHSU/ PSU/ UW |
| J18 | Acoustic Tracking for Survival (POST) | 2003-114-00 | P3 | Kintama |
| J19 | Relationship Among Time of Ocean Entry, Physical, & Biological Characteristics of Estuary/Plume | EST-P-02-03 | P6 | NMFS |
| J20 | Effectiveness Monitoring at Sites in Young's Bay | Unknown | P19 | CREST |
| J21 | Habitat Restoration Program – Habitat GIS, Reference Sites, Restoration Actions Effectiveness Research and Pile Structure Modification Critical Uncertainties | 2003-011-00 | P14 + P3 | Estuary Partnership |
| J22 | Monitoring at Smith and Bybee Lakes | Unknown | Unknown | Ducks Unlimited |

| ID | Title | Project No. | Program | Monitoring Entity |
|---|---|---|---|---|
| J23 | Ramsey Lake Restoration Project Monitoring | Unknown | 14 | City of Portland |
| J24 | Impact of American Shad | 2007-275-00 | P3 | USGS |
| J25 | Caspian Tern Management | 2006-002-00 | P3 | OSU |
| J26 | Tidal Freshwater Monitoring of Juvenile Salmonids | 2005-001-00 | P3 | PNNL/ODFW/UW/NMFS |
| J27 | Effects of Total Dissolved Gas on Chum Fry | SPE-P-07-01 | P6 | PNNL |
| J28 | CORIE | Unknown | P3+ | OHSU |
| J29 | Pile Structure Removal and Modification Study | Unknown | P14 | Estuary Partnership/BPA/ USACE |
| J30 | Julia Butler Hansen Tide Gate Replacement | Unknown | P11 | USFWS |
| J31 | Comparison of Juvenile Salmonid Stranding Before and After Channel Improvements | Unknown | P4 | PNNL/UW |
| J32 | Bonneville Sea Lion Exclusion Study | ADS-02-16 | P6 | USCAE Fisheries Field Unit |
| J33 | Sea Lion Deterrent System | BPA/NPCC | P3 | Smith Root |
| J34 | Caspian Tern Management Measures | AVS-P-08-01 | P6 | OSU |
| J35 | Double-Crested Cormorant Management Measures | AVS-P-08-02 | P6 | OSU |
| J36 | Impact of Avian Predation on Smolts | AVS-W-03-01 | P6 | NMFS |
| J37 | Tides and currents | Unknown | P15 | NOAA |
| J38 | Northern Pikeminnow Surveys | 1990-077-00 | P3 | ODFW |
| J39 | Effectiveness Monitoring in the Lower Grays R. | PNAMP#529 | P3 | CREST |
| J40 | Ives Island – Adult Chum Salmon Monitoring | PNAMP#277 | P3 | ODFW |
| J41 | Volunteer Water Quality Monitoring | PNAMP#575 | P17 | Willamette River Keeper |
| J42 | Zebra Mussel Monitoring | PNAMP#425 | P18 | PSU |

TABLE 6-4
Management Actions, Associated Monitoring Needs, and Existing Coverage
*Existing projects with "J" prefixes refer to projects listed in Table 6-3.*

| Management Action | Type | Monitoring Need | Existing Projects and Gaps |
|---|---|---|---|
| CRE-1: Protect intact riparian areas in the estuary and restore riparian areas that are degraded. | STM | Periodic mapping and areal measurement of riparian habitats and their condition using aerial photography to inform prioritization efforts | J5 and J21, although the projects do not do this at this time, but eventually could. |
| CRE-2: Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures. | STM | Water temperature monitoring in the estuary to establish baseline | J1, J2, J28 |
| | AER | Monitoring during the hydrosystem temperature experiment | At dams, the US Army Corps of Engineers (USACE) monitors water temperature; revive hydrodynamic modeling |
| | UR | Reservoir heating study and downstream effects | No existing projects. |
| CRE-3: Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries. | STM | Continuous monitoring of Col. River discharge at Beaver Terminal in the estuary | J3 USGS National Streamflow Information Program |
| CRE-4: Adjust the timing, magnitude and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume. | STM/ AER | Continuous monitoring of Col. River discharge at Beaver Terminal in the estuary and at Bonneville dam<br>Plume turbidity monitoring using remote sensing | J3 USGS National Streamflow Information Program; J36 NOAA Tides and Currents |
| | UR | Flood, habitat, and constraints study(s) | No existing projects; revive modeling, e.g., Jay and Kukulka 2003 |
| CRE-5: Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume. | UR | Effects of reservoir sediment entrapment | No existing projects; the USACE measured sediment entrapment previously. |
| CRE-6: Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially. | UR | Evaluate the long-term trajectory of beneficial use of shallow- water habitat creation sites | No existing projects; the USACE applies dredged material for beneficial uses when possible |
| CRE-7: Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary. | UR | Dredge technique and operations study | No existing projects; the USACE studied crab entrainment previously (Pearson et al. 2006). |
| CRE-8: Remove or modify pilings and pile dikes when removal or modification would benefit juvenile salmonids and improve ecosystem health. | STM | Periodic mapping and length and density measurements of pile structures using the Estuary Partnership's estuary GIS system | J29, J21 |
| | AER | Monitor physical and biological effects of pile removal | J29, J21 |
| | UR | Study fundamental physical and biological characteristics to understand where removal or modification would be advantageous | No existing projects. |

| Management Action | Type | Monitoring Need | Existing Projects and Gaps |
|---|---|---|---|
| CRE-9: Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat. | STM | Periodic mapping and areal measurement of off-channel habitat types to inform prioritization and monitoring efforts | J5 and J21 |
| CRE-10: Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats. | STM | Periodic mapping and length measurements of dike structures using the Estuary Partnership's estuary GIS system. | J21 GIS map of dikes and tide gates |
| | AER | Effectiveness monitoring studies of tidal reconnections | J30 JBH study, J15 Cumulative effects, J20 Young's Bay |
| | UR | Ecological importance of tidal reconnections | J15 Cumulative effects<br>J17 Habitat linkages |
| CRE-11: Reduce the square footage of over-water structures in the estuary. | STM | Periodic mapping and areal measurements of over-water structures using the Estuary Partnership's estuary GIS system.<br>Track permits for construction of shoreline structures | J21 GIS map of over-water structures – needs to be expanded to areal extent, not just linear extent |
| | UR | Study fundamental physical and biological characteristics to understand where removal would be advantageous | No existing projects in the estuary. |
| CRE-12: Reduce the effects of vessel wake stranding in the estuary. | STM | Total stranding estimate for entire estuary | No existing projects. |
| | UR | Factors and stranding reduction study | J31 Before/after CRCIP addresses factors |
| CRE-13: Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids. | STM | Monitor trends in predator abundance | J38 |
| CRE-14: Identify and implement actions to reduce salmonid predation by pinnipeds. | STM | Pinniped predation monitoring | J32 |
| | AER | Effectiveness of actions. Monitor actions under Section 120 of the Marine Mammal Protection Act | J32, J33<br>Section 120 monitoring |
| | UR | Magnitude of pinniped impact in the estuary | J32 (at BON) - expand to include magnitude of impact throughout estuary |
| CRE-15: Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of invasive plants. | STM | Inventory and map invasive plants | No existing projects; revive Sytsma et al. 2004 |
| | AER | Effectiveness monitoring | Wahkiakum. Community Foundation Columbia Estuary Environmental Education Program (LCEEEP) identification and treatment of invasive weeds on Julia Butler Hansen Wildlife Refuge |
| CRE-16: Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island. | STM | Tern monitoring | J25, J34 Tern monitoring |
| | AER | Effectiveness of habitat shift | J25, J34 Tern management |
| CRE-17: Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations. | STM | Cormorant monitoring | J35 |
| | AER | Methods to reduce cormorant abundance | J35 Cormorant management |

| Management Action | Type | Monitoring Need | Existing Projects and Gaps |
|---|---|---|---|
| CRE-18: Reduce the abundance of shad in the estuary. | STM | Monitor passage of adult shad at Bonneville Dam | USACE Fish counting |
| | AER | Evaluate effectiveness of control methods | No existing projects. |
| | UR | Assess ecological effects of shad | J24 Shad impact study |
| CRE-19: Prevent new introductions of aquatic invertebrates and reduce the effects of existing infestations. | STM | Monitor trends in abundance, distribution, and species composition of invertebrate invasives | No existing projects; revive Sytsma et al. 2004 |
| CRE-20: Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary. | STM | WQ/toxics monitoring downstream of Bonneville Dam | No existing projects. |
| | AER | Pre- and post-project monitoring | No existing projects. |
| | UR | Source tracking; fish health; sublethal and lethal thresholds | No existing projects; J5; no existing projects. |
| CRE-21: Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants. | STM | WQ/toxics monitoring | No existing projects; minimal WQ in J1, J2, J3, J5 |
| | AER | Pre- and post-project monitoring | No existing projects. |
| | UR | Source tracking; fish health; sublethal and lethal threshold. | No existing projects; J5; none |
| CRE-22: Restore or mitigate contaminated sites. | STM | WQ/toxics monitoring | No existing projects; minimal WQ in J1, J2, J5 |
| | AER | Pre- and post-project monitoring | No existing projects. |
| | UR | Source tracking; fish health; sublethal and lethal thresholds | No existing projects; J5; none |
| CRE-23: Implement stormwater best management practices in cities and towns. | STM | Stormwater monitoring | No existing projects; limited monitoring with NPDES permit requirements |
| | AER | Directed stormwater monitoring | No existing projects. |
| | UR | Source tracking; improve BMPs and regulations | No existing projects. |

TABLE 6-5
Recommended New RME Projects or New Objectives in Existing Projects
*These projects would fill gaps where "no existing projects" were noted in Table 6-4.*

| Action | Type | Project |
|---|---|---|
| CRE-2 | UR | Water temperature monitoring and modeling for a reservoir heating study |
| CRE-4 | UR | Flood, habitat, and constraints study(s) of the effects of "more normative" flows in the estuary |
| CRE-5 | UR | Measurement of sediment entrapment in mainstem Columbia River reservoirs |
| CRE-6 | UR | Demonstration study of beneficial use of dredged material to create shallow-water habitat |
| CRE-7 | UR | Dredging technique and operations to minimize entrainment of juvenile salmonids |
| CRE-8 | UR | Study fundamental physical and biological characteristics to understand where removal would be advantageous |
| CRE-11 | UR | Assessment of impacts and benefits of removing over-water structures |
| CRE-12 | STM | Total, estuary-wide stranding estimates by species of juvenile salmonid |
| CRE-15 | STM | Routine monitoring of percent cover and distribution of invasive plants by species |
| CRE-18 | AER | Effectiveness study of shad control methods |
| CRE-19 | STM | Routine monitoring of percent cover and distribution of invasive aquatic invertebrates by species |
| CRE-20, 21, 22, 23 | STM | Water quality, stormwater, and toxic contaminants monitoring below Bonneville Dam |
| CRE-20, 21, 22, 23 | AER | Pre- and post-project implementation water quality, stormwater and toxic contaminants monitoring below Bonneville Dam |
| CRE-20, 21, 22, 23 | UR | Determine sources, concentrations, timing, types, and pathways of water quality and toxic contaminant pollutants; sublethal and lethal thresholds in fish and food web |

TABLE 6-6
Monitoring Guidance for Estuary Recovery Plan Module RME. Adapted from Appendix C, Johnson et al. (2008).

| Mngt. Action | Monitoring Need[1] | Sampling Design | Spatial/ Temporal Scale | Measured Variables | Measurement Protocols | Derived Variables | Analysis | Possible Funding Entities | Possible Implementation & Coordination |
|---|---|---|---|---|---|---|---|---|---|
| CRE-1 | Periodic mapping and areal measurement of riparian habitats and their condition | Complete census with ground-truthing | Estuary-wide every 5 years | Length of riparian habitat by type of habitat | GIS-linked aerial photography, Landsat imagery and videography (Evans et al. 2006) | Proportions for each riparian habitat type | Trend analysis | BPA/NPCC, USACE, NOAA | Estuary Partnership |
| CRE-2 | Water temperature monitoring in the estuary to establish baseline | Stratified random sampling by reach | At representative sites throughout the estuary essentially continuously | Water temperature | Data loggers (Callaway et al. 2001) | Maximum daily/weekly maximum, seasonal averages | Trend analysis | BPA/NPCC, USGS | BPA/NPCC Fish and Wildlife Program |
| | Hydrosystem temperature experiment | Modeling | Estuary-wide | Water temperature | Hydrodynamic model | Maximum daily/weekly maximum, seasonal averages | Compare/ contrast | BPA/NPCC, EPA, USGS | Ibid. |
| | Reservoir heating study and downstream effects | Systematic sampling and modeling | At representative sites throughout the estuary essentially continuously | Water temperature | Data loggers (Callaway et al. 2001) | Maximum daily/weekly maximum, seasonal averages | Compare/ contrast | BPA/NPCC | Ibid. |
| CRE-3 | Continuous monitoring of Columbia River discharge at Beaver Terminal in the estuary | Systematic sampling | Hourly sampling at Beaver Terminal | Stream discharge (cfs) | USGS gauging station | Annual maximum and minimum, seasonal averages | Trend analysis | USGS | USGS program |

| Mngt. Action | Monitoring Need[1] | Sampling Design | Spatial/ Temporal Scale | Measured Variables | Measurement Protocols | Derived Variables | Analysis | Possible Funding Entities | Possible Implementation & Coordination |
|---|---|---|---|---|---|---|---|---|---|
| CRE-4 | Continuous monitoring of Columbia River discharge at Beaver Terminal in the estuary and at Bonneville Dam | Systematic sampling | Hourly sampling at Beaver Terminal and BON | Stream discharge (cfs) | USGS gauging station | Annual maximum and minimum, seasonal averages | Trend analysis | USGS, USACE | USGS program (See CRE-3); also USACE O&M program for mainstem dams |
| | Plume turbidity monitoring using remote sensing | Complete census with ground-truthing | Plume-wide every 5 years | Turbidity | GIS-linked aerial photography | Time series of turbidity maps | Trend analysis | BPA/NPCC, NOAA | BPA/NPCC Fish and Wildlife Program (See CRE-2) |
| | Flood, habitat, and constraints effects study(s) | Modeling effort | Estuary-wide | Inundation | Hydrodynamic model | Cumulative inundation curves | Compare/ contrast | BPA/NPCC, NOAA | USACE's AFEP |
| CRE-5 | Effects of reservoir sediment entrapment | Complete census | All 13 main-stem Snake and Columbia dams every 5 years | Thickness of reservoir sediment | Acoustic bottom typing (multibeam sonar) | Sediment maps | Trend analysis | USACE | USACE's AFEP (See CRE-4) |
| CRE-6 | Evaluation of beneficial use of dredged material – create shallow-water habitat | Before-after-control-impact (BACI) | Site-specific, 1 year before and 5 years after | Vegetation, bathymetry | Roegner et al. 2009, bathymetry | Percent cover, shallow-water habitat | Effectiveness evaluation | USACE | USACE's Sediment Management Program |
| CRE-7 | Dredge technique and operations study | Focused field experiments | TBD | Crab entrainment | Pearson et al. 2006 | Entrainment rates | Statistical analysis | USACE | USACE's Sediment Management Program (See CRE-6) |
| CRE-8 | Periodic mapping and length and density measurements of pile structures | Complete census with ground-truthing | Estuary-wide every 5 years | Length of pile structure | GIS-linked videography (Evans et al. 2006) | Length and locations of pile structure | Trend analysis | BPA/NPCC, USACE, NOAA | Estuary Partnership (See CRE-1) |
| | Monitor physical and biological effects of pile removal | BACI | Site-specific, 1 year before and 3 years after | Water velocity, fish species composition and abundance | Data loggers (Callaway et al. 2001), fish by Roegner et al. 2009 | Annual max and min velocity, fish species composition proportions | Effectiveness evaluation | USACE | Ibid. |

| Mngt. Action | Monitoring Need[1] | Sampling Design | Spatial/ Temporal Scale | Measured Variables | Measurement Protocols | Derived Variables | Analysis | Possible Funding Entities | Possible Implementation & Coordination |
|---|---|---|---|---|---|---|---|---|---|
| | Study fundamental physical and biological characteristics to understand where removal would be advantageous | Systematic sampling | Selected sites for all four seasons over 3 years | Ibid. | Ibid. | Ibid. | Ecological characterization | Ibid. | Ibid. |
| CRE-9 | Periodic mapping and areal measurement of off-channel habitat types | Complete census with ground-truthing | Estuary-wide every 5 years | Length of riparian habitat by type of habitat | GIS-linked aerial photography | Amount of off-channel habitat | Trend analysis | BPA/NPCC, USACE, NOAA | Estuary Partnership (See CRE-1, 8) |
| CRE-10 | Periodic mapping and length measurements of dike structures | Complete census with ground-truthing | Estuary-wide every 5 years | Length of dike/levee structures | GIS-linked aerial photography | Length of dike/levee structures | Trend analysis | BPA/NPCC, USACE, NOAA | Estuary Partnership (See CRE-1, 8, 9) |
| | Effectiveness monitoring studies of tidal reconnections | BACI | Site-specific, 1 year before and 5 years after | Hydrology, vegetation, fish | Roegner et al. 2009 | Water surface elevation, percent cover, fish species comosition proportions | Statistical comparison | BPA/NPCC, USACE, NOAA | Estuary Partnership (See CRE-1, 8, 9), BPA/NPCC Fish and Wildlife Program (See CRE-2, 4), USACE's AFEP (See CRE-4,5) |
| | Ecological importance of tidal reconnections | BACI | Site-specific, 1 year before and 5 years after | Prey availability, fish diet, fish residence time, fish stock | Roegner et al. 2009 | Diet composition charts | Ecological characterization | BPA/NPCC, USACE, NOAA | Ibid. |
| CRE-11 | Periodic mapping and areal measurements of over-water structures | Complete census with ground-truthing | Estuary-wide every 5 years | Length of over-water structures | GIS-linked aerial photography and videography | Length of over-water structures | Trend analysis | BPA/NPCC, USACE, NOAA | Estuary Partnership (See CRE-1, 8, 9, 10) |
| | Track construction permits for shoreline structures | Census | Estuary-wide annually | No. and location of shoreline structures | Contact permitting agencies | Map of structures planned or under construction | Trend analysis | USACE | USACE Regulatory Program |

| Mngt. Action | Monitoring Need[1] | Sampling Design | Spatial/ Temporal Scale | Measured Variables | Measurement Protocols | Derived Variables | Analysis | Possible Funding Entities | Possible Implementation & Coordination |
|---|---|---|---|---|---|---|---|---|---|
| | Study fundamental physical and biological characteristics | Systematic sampling | Selected sites for all four seasons over 3 years | Water velocity, light, fish species composition and abundance | Data loggers (Callaway et al. 2001), fish by Roegner et al. 2009 | Annual max and min velocity and light levels, fish species composition proportions | Ecological characterization | USACE, NOAA | Estuary Partnership (See CRE-1, 8, 9, 10), BPA/NPCC Fish and Wildlife Program (See CRE-2, 4, 10), USACE's AFEP (See CRE-4, 5, 10) |
| CRE-12 | Total stranding estimate for entire estuary | Stratified random sampling by reach | Estuary-wide over all four seasons of 1 year | Number of juvenile salmonids stranded | Direct counts | Extrapolation to total no. stranded; map of stranding densities | Correlation analysis of factors associated with stranding | USACE | USACE's Channel Improvement Project |
| | Factors and stranding reduction study | BACI | Selected sites | Ibid. | Ibid. | Average no. stranded w/ and w/o the reduction device | Statistical comparison | USACE | Ibid. |
| CRE-13 | Monitor trends in piscivorous predator abundance | Stratified random sampling by reach | Estuary-wide annually | Catch per unit effort | Electrofishing | Predator densities by location | Trend analysis | BPA/NPCC, USACE, NOAA | USACE's AFEP (See CRE-4, 5, 10, 11) |
| CRE-14 | Pinniped predation monitoring | Systematic sampling | At BON during spring and summer | Number of pinnipeds | Observers | Weekly average abundance | Trend analysis | BPA/NPCC, USACE | USACE's AFEP (See CRE-4, 5, 10, 11, 13) |
| | Effectiveness of actions (monitor actions under Sec. 120) | BACI | Ibid. | Ibid. | Ibid. | Average abundance | Statistical comparison | USACE | Ibid. |
| | Magnitude of pinniped impact | Stratified random sampling by reach | Estuary-wide annually | Number of pinnipeds; number of salmon and steelhead consumed per predator; sampling rate | Observers, scat analysis | Estimate of the total number of salmon and steelhead consumed | Trend analysis | NOAA | Ibid. |

| Mngt. Action | Monitoring Need[1] | Sampling Design | Spatial/ Temporal Scale | Measured Variables | Measurement Protocols | Derived Variables | Analysis | Possible Funding Entities | Possible Implementation & Coordination |
|---|---|---|---|---|---|---|---|---|---|
| CRE-15 | Inventory and map invasive plants | Stratified random sampling by reach | Estuary-wide every 5 years | Species composition, abundance, distribution | Site surveys (Sytsma et al. 2004) | Percent cover, maps | Trend analysis | BPA/NPCC, USACE, NOAA | Estuary Partnership (See CRE-1, 8, 9, 10, 11) |
| | Effectiveness monitoring | BACI | At selected sites over 3 years | Ibid. | Ibid. | Average percent cover | Statistical comparison | Ibid. | Ibid. |
| CRE-16 | Tern monitoring | Systematic sampling | Reach A during April-August annually | Number of birds | Observers | Number of mating pairs, total local population size | Trend analysis | BPA/NPCC, USACE, NOAA, USFWS | USACE's AFEP (See CRE-4, 5, 10, 11, 13, 14) |
| | Effectiveness of habitat shift | BACI | Reach A during April-August for 3-5 years | Ibid. | Ibid. | Ibid. | Statistical comparison | Ibid. | Ibid. |
| CRE-17 | Double-crested cormorant monitoring | Systematic sampling | Reach A during April-August annually | Number of birds | Observers | Number of mating pairs, total local population size | Trend analysis | BPA/NPCC, USACE, NOAA, USFWS | USACE's AFEP (See CRE-4, 5, 10, 11, 13, 14, 16) |
| | Methods to reduce cormorant abundance | Site experiments | Reach A over 1-3 years | Ibid. | Ibid. | Ibid. | Compare/ contrast | Ibid. | Ibid. |
| CRE-18 | Monitor passage of adult shad at BON | Census | Continuous monitoring at BON | Number of adult shad | Observers | Total number per year, weekly and monthly averages | Trend analysis | USACE | BPA/NPCC Fish and Wildlife Program (See CRE-2, 4, 10, 11), USACE's AFEP (See CRE-4, 5, 10, 11, 13, 14, 16, 17) |
| | Evaluate effectiveness of control methods | Site experiments | Selected sites | Ibid. | Seine, sonar | Number of shad by treatment | Statistical comparison | BPA/NPCC, USACE, NOAA | Ibid. |
| | Assess ecological effects of shad | Systematic sampling | Selected sites for summer over 3 years | Number of shad, diet, distribution, sex ratio | Various | Total population size, fecundity, etc. | Ecological characterization | BPA/NPCC | Ibid. |

| Mngt. Action | Monitoring Need[1] | Sampling Design | Spatial/ Temporal Scale | Measured Variables | Measurement Protocols | Derived Variables | Analysis | Possible Funding Entities | Possible Implementation & Coordination |
|---|---|---|---|---|---|---|---|---|---|
| CRE-19 | Monitor trends in abundance, distribution, and species composition of invasive invertebrates | Stratified random sampling by reach | Estuary-wide every 5 years | Species composition, abundance, distribution | Site surveys (Sytsma et al. 2004) | Density distribution maps | Trend analysis | BPA/NPCC, USACE, NOAA | Estuary Partnership (See CRE-1, 8, 9, 10, 11, 15) |
| CRE-20, 21, 22, 23 | Water quality and toxics monitoring downstream of BON | Stratified random sampling by reach, directed source and load tracking | Estuary-wide annual | Concentrations and loads of pollutants, contaminants by source and type | Various | Maps of distribution of pollutant concentration loads, pathways, and sources by type | Every 3 years - trend analysis; concentration loads, and yields by tributary and source | EPA, NOAA, USGS, ODEQ, WDOE | Estuary Partnership (See CRE-1, 8, 9, 10, 11, 15, 19) |
| | Fish health, sublethal and lethal thresholds | Focused experiments | Laboratory | Fish health/ mortality | Ibid. | Dose response curves | Statistical analysis | Ibid. | Ibid. |

[1]Monitoring needs are those identified in Table 6-4.

TABLE 6-7
Estimated Cost and Schedule for Monitoring Needs (includes ongoing projects in some cases)

| Management Action | Monitoring Need | Unit | Est. Cost | Schedule |
|---|---|---|---|---|
| CRE-1: Protect intact riparian areas in the estuary and restore riparian areas that are degraded. | Periodic mapping and areal measurement of riparian habitats and their condition using aerial photography to inform prioritization efforts | Every 5 years, base flyover for data acquisition @ $250K and analysis for riparian zones @ $200K | $1M base plus $800K riparian | 2007-2022 |
| CRE-2: Operate the hydrosystem to reduce the effects of reservoir surface heating, or conduct mitigation measures. | Water temperature monitoring in the estuary to establish baseline | Continuous monitoring at four sites (Bonneville Dam, Beaver, St. Helens, and Astoria) for 3 years @ $20K per year and one retrospective study of temperature | $60K (new data from Beaver, St. Helens) plus $50K study | 2007-2009 |
| | Monitoring during the hydrosystem temperature experiment | Continuous monitoring at four sites (Bonneville Dam, Beaver, St. Helens, and Astoria) for 5 years @ $20K per year | $100K | 2010-2014 |
| | Reservoir heating study and downstream effects | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| CRE-3: Protect and/or enhance estuary instream flows influenced by Columbia River tributary/mainstem water withdrawals and other water management actions in tributaries. | Continuous monitoring of Columbia River discharge at Beaver Terminal in the estuary | Data collection and dissemination are routine and ongoing. | $0 (already covered) | 2007-2035 |
| CRE-4: Adjust the timing, magnitude and frequency of hydrosystem flows (especially spring freshets) entering the estuary and plume to better reflect the natural hydrologic cycle, improve access to habitats, and provide better transport of coarse sediments and nutrients in the estuary and plume. | Continuous monitoring of Columbia River discharge at Beaver Terminal in the estuary and at BON dam | See CRE-3 | $0 (already covered) | 2007-2035 |
| | Plume turbidity monitoring using remote sensing (satellite) | 3 years @ $100K/year | $300K | 2009-2011 |
| | Flood, habitat, and constriant study(s) | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| CRE-5: Study and mitigate the effects of entrapment of fine sediment in reservoirs, to improve nourishment of the estuary and plume. | Effects of reservoir sediment entrapment | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| CRE-6: Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially. | Evaluate the beneficial use of dredged material – create shallow-water habitat | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| CRE-7: Reduce entrainment and habitat effects resulting from main- and side-channel dredge activities and ship ballast intake in the estuary. | Dredge technique and operations study | see Table 5-6 | see Table 5-6 | see Table 5-6 |

| Management Action | Monitoring Need | Unit | Est. Cost | Schedule |
|---|---|---|---|---|
| CRE-8: Remove or modify pilings and pile dikes when removal or modification would benefit juvenile salmonids and improve ecosystem health. | Periodic mapping and length and density measurements of pile structures using the Estuary Partnership's estuary GIS system | One assessment every 5 years @ $200K per assessment | $800K | 2007-2022 |
| | Monitor physical and biological effects of pile removal | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| | Study fundamental physical and biological characteristics to understand where removal would be advantageous | One study for 3 years @ $250K/year | $750K | 2007-2009 |
| CRE-9: Protect remaining high-quality off-channel habitat from degradation and restore degraded areas with high intrinsic potential for high-quality habitat. | Periodic mapping and areal measurement of off-channel habitat types to inform prioritization and monitoring efforts | See CRE-1 cost for base flyover, plus analysis of off-channel habitats every 5 years @ $200K per assessment | $800K | 2007-2022 |
| CRE-10: Breach, lower, or relocate dikes and levees to establish or improve access to off-channel habitats. | Periodic mapping and length measurements of dike structures using the Estuary Partnership's estuary GIS system. | See CRE-9; additional analysis @ $50K per assessment every 5 years | $200K | 2007-2022 |
| | Effectiveness monitoring studies of tidal reconnections | Two case studies each in Reaches A-E and one study each in Reaches F-H with samplings in Years 0, 1, 4, 7 @ $100K per sampling-year | $5.2M | 2007-2035 |
| | Ecological importance of tidal reconnections | Building on the data from the effectiveness monitoring, one study for 5 years @ $400K per year | $2M | 2007-2011 |
| CRE-11: Reduce the square footage of over-water structures in the estuary. | Periodic mapping and areal measurements of over-water structures using the Estuary Partnership's estuary GIS system. | Assessments every 5 years @ $250K per assessment | $1M | 2007-2022 |
| | Track permits for construction of shoreline structures | Annual compilation and reporting @ $60K per year | $1.5M | 2007-2031 |
| | Study fundamental physical and biological characteristics to understand where removal would be advantageous | One study for 3 years @ $250K/year | $750K | 2008-2010 |
| CRE-12: Reduce the effects of vessel wake stranding in the estuary. | Total stranding estimate for entire estuary | One study with sampling three seasons per year at eight sites for 2 years @ $1M per yr | $2M | 2009-2010 |

| Management Action | Monitoring Need | Unit | Est. Cost | Schedule |
|---|---|---|---|---|
| | Factors and stranding reduction study | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| CRE-13: Manage pikeminnow and other piscivorous fish, including introduced species, to reduce predation on salmonids. | Monitor trends in predator abundance | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| CRE-14: Identify and implement actions to reduce salmonid predation by pinnipeds. | Pinniped predation monitoring | One study estuary-wide for 5 years @ $250K per year | $2.5M | 2008-2012 |
| | Effectiveness of actions. Monitor actions under Sec. 120 | Study every 5 years for 20 years @ $200K (see above) | $0 (already covered) | 2013-2032 |
| | Magnitude of pinniped impact in estuary | See pinniped predation monitoring above | $0 (already covered) | 2008-2012 |
| CRE-15: Implement education and monitoring projects and enforce existing laws to reduce the introduction and spread of invasive plants. | Inventory and map invasive plants | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| | Effectiveness monitoring | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| CRE-16: Implement projects to redistribute part of the Caspian tern colony currently nesting on East Sand Island. | Tern monitoring | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| | Effectiveness of habitat shift | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| CRE-17: Implement projects to reduce double-crested cormorant habitats and encourage dispersal to other locations. | Cormorant monitoring | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| | Methods to reduce cormorant abundance | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| CRE-18: Reduce the abundance of shad in the estuary. | Monitor passage of adult shad at Bonneville Dam | Data collection and dissemination are routine and ongoing. | $0 (already covered as part of adult fish counts) | 2007-2035 |
| | Evaluate effectiveness of control methods | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| | Assess ecological effects of shad | One study for 3 years @ $300K per year | $900K | 2008-2010 |
| CRE-19: Prevent new introductions of aquatic invertebrates and reduce the effects of existing infestations. | Monitor trends in abundance, distribution, and species composition of invasive invertebrates | Recurring study every 3 years for 30 years @ $500K per year | $5M | 2008-2037 |

| Management Action | Monitoring Need | Unit | Est. Cost | Schedule |
|---|---|---|---|---|
| CRE-20: Implement pesticide and fertilizer best management practices to reduce estuarine and upstream sources of nutrients and toxic contaminants entering the estuary. | WQ/toxics monitoring downstream of Bonneville Dam | Annual ambient and directed sampling for 25 years @ $1M/year | $25M | 2008-2032 |
| | Pre- and post-project monitoring | Twice annual upstream + downstream sites @ $10K per project @ one project per year for 25 years | $250,000 | 2008-2032 |
| | Source tracking, fish health, sublethal and lethal thresholds | One study for 5 years @ $500K; fish health @ 5-6 sites per year @ $250K for 25 years; one study for eight priority toxics @ $1.5M for 3 years | $8.25M | 2008-2032 |
| CRE-21: Identify and reduce terrestrially and marine-based industrial, commercial, and public sources of pollutants. | WQ/toxics monitoring | See CRE-20 | See CRE-20 | See CRE-20 |
| | Pre- and post-project monitoring | Ibid. | Ibid. | Ibid. |
| | Source tracking, fish health, sublethal and lethal thresholds | Ibid. | Ibid. | Ibid. |
| CRE-22: Restore or mitigate contaminated sites. | WQ/toxics monitoring | See CRE-20 | See CRE-20 | See CRE-20 |
| | Pre- and post-project monitoring | Ibid. | Ibid. | Ibid. |
| | Source tracking, fish health, sublethal and lethal thresholds | Ibid. | Ibid. | Ibid. |
| CRE-23: Implement stormwater best management practices in cities and towns. | Stormwater monitoring | see Table 5-6 | see Table 5-6 | see Table 5-6 |
| | Directed stormwater monitoring | Twice annual @ 5 cities @ $24K per site for 25 years | $3M | 2008-2032 |
| | Source tracking, improve BMPs and regulations | 1 study for 5 years @ $500K (see CRE-20); 1 study for 3 years @ $1.5M | $2M | 2008-2013 |

CHAPTER 7

# Perspectives on Implementation

Substantial investment is being made in the Columbia River basin to recover listed Chinook, coho, steelhead, and chum. How much of this investment should be made in the estuary? How much do the estuary and plume environments contribute to the survival of upstream ESUs, and is recovery of upstream ESUs possible without a healthier estuary ecosystem? If not, what does the information in Chapters 3, 4, and 5 tell us about which management actions to implement in the estuary?

Chapter 7 explores issues related to the selection of management actions to be implemented in the estuary and how those choices will shape future conditions for salmonids in the estuary and plume. It also suggests next steps in implementation and identifies implementation challenges.

## Putting the Estuary in Context

This recovery plan module reflects current scientific understanding that the Columbia River estuary and plume provide habitat that wild salmonids need to complete their life cycles. Historically, juveniles from hundreds of distinct salmonid populations, at various life history stages, used the estuary for refuge and rearing as they prepared physiologically for life in the ocean. Over evolutionary time populations developed life history strategies in which juveniles from different populations staggered their use of the estuary throughout the year, exploiting estuarine habitats in different ways for different lengths of time. Although the estuary posed risks to juvenile salmonids, the diversity in life history strategies allowed salmon and steelhead to take maximum advantage of estuarine resources, which offered tremendous opportunities for refuge and growth. Unlike an upstream tributary, through the year the estuary provided habitat for all of the salmonid populations in the Columbia River basin during a critical stage in their life cycles.

Over the last 200 years the ability of the Columbia River estuary to meet the needs of salmon and steelhead has been seriously compromised. There is no question about the extent of changes in the estuary: the timing, magnitude, and duration of flows do not resemble those of historical flows, access to the estuary floodplain has been virtually eliminated, sediment transport processes that depend on flows and upstream sediment sources are radically different than they were historically, water quality has degraded as a result of contamination, temperatures are approaching and sometimes exceeding lethal limits, and there have been fundamental changes at the base of the estuarine food web, with associated alterations in inter- and intra-species relationships. A central premise of this recovery plan module is that although the estuary ecosystem is degraded, it can be improved, and that a healthier estuary ecosystem would contribute meaningfully to the basinwide recovery of ESA-listed salmonids.

# Factors That Influence Decision Making

Decisions about implementation would be easy if protecting and restoring salmonids were the only consideration. However, as much as we value healthy native fish runs, as a society we also value a stable economy, financial opportunity for individuals and businesses, public safety, and property rights. These values will play into decisions about which management actions to implement, as will the three factors used to evaluate the management actions in Chapter 5: cost, constraints, and potential benefits to salmonids.

Also affecting choices about implementation is scientific uncertainty. Although fisheries science has matured over the last 100 years, how salmonids interact in complex ecosystems is not well understood; this is especially true in the estuary and plume. Yet we cannot wait until uncertainty has been eliminated before taking action. In the face of scientific uncertainty, then, decisions about implementing management actions will have to be made using the most current scientific information available, combined with best professional judgment. Historically, it has been a mix of science and policy choices that have guided decisions that affected the estuary; it is likely that these same forces will also determine the effectiveness of science-driven recovery efforts.

## Significance of Constraints to Implementation

Not a single management action identified in Table 5-1 will be easy to implement. In one way or another, implementation of each of the 23 actions is constrained, in some cases greatly. Understanding the nature and magnitude of constraints to the implementation of management actions is important for several reasons. First, it grounds the actions in the real world and tempers expectations for results. Second, it provides insights into the level of effort that would be required for an action to have a sizable impact on salmonid populations. Third and most important, it reveals that every proposed action in this recovery plan module has significant obstacles to implementation.

Because it will be difficult to implement any single action fully and gain all of its potential benefit to salmonids, it will be important to implement a relatively large number of the proposed management actions. In other words, if each management action in the estuary has significant constraints, it may take partial implementation of all or most of the actions to improve the health of the estuary ecosystem to the point that the ecosystem provides the benefits that salmonids need to recover.

To illustrate the relative constraints of different actions, Table 7-1 presents management actions by degree of constraint to implementation, in descending order.

**Table 7-1**
Management Actions Sorted by Degree of Constraint

| # | Action | Degree of Constraint |
|---|---|---|
| CRE-02 | Operate the hydrosystem to reduce reservoir heating. | 5 |
| CRE-03 | Protect/enhance instream flows influenced by water withdrawals and other water management actions in tributaries. | 5 |
| CRE-04 | Adjust the timing, magnitude, and frequency of hydrosystem flows. | 5 |
| CRE-05 | Mitigate entrapment of fine sediment in reservoirs. | 5 |
| CRE-18 | Reduce shad abundance. | 5 |
| CRE-19 | Prevent aquatic invertebrate introductions. | 5 |
| CRE-14 | Reduce predation by pinnipeds. | 4 |
| CRE-15 | Reduce invasive plants. | 4 |
| CRE-17 | Redistribute cormorants. | 4 |
| CRE-21 | Identify and reduce sources of pollutants. | 4 |
| CRE-20 | Implement pesticide/fertilizer BMPs. | 4 |
| CRE-9 | Protect/restore high-quality off-channel habitat | 3 |
| CRE-10 | Breach, lower, or relocate dikes and levees. | 3 |
| CRE-12 | Reduce vessel wake stranding. | 3 |
| CRE-22 | Restore or mitigate contaminated sites. | 3 |
| CRE-11 | Reduce over-water structures. | 3 |
| CRE-01 | Protect/restore riparian areas. | 3 |
| CRE-06 | Use dredged materials beneficially. | 3 |
| CRE-16 | Redistribute Caspian terns. | 2 |
| CRE-07 | Reduce entrainment/habitat effects of dredging and ballast. | 2 |
| CRE-13 | Manage pikeminnow and other piscivorous fish. | 2 |
| CRE-23 | Implement stormwater BMPs. | 2 |
| CRE-08 | Remove or modify pilings and pile dikes | 2 |

Another useful table when considering implementation constraints is Table 5-3, which shows the differences in potential benefit to salmonids if implementation of actions is unconstrained, versus constrained, which represents a more realistic scenario. However, although Table 5-3 demonstrates the size of the gap between unconstrained and constrained implementation of actions, it does not adequately characterize the magnitude of response that might be expected from constrained implementation. The next section of this document is intended to help show the potential benefit from constrained implementation of actions.

## Management Actions Offering the Greatest Survival Benefits

If we were to increase our investment in restoration of the Columbia River estuary by an order of magnitude, what would the ecological return on that investment be? Our ability to answer that question is limited by a lack of understanding of how much mortality actually occurs in the estuary and plume. Still, we do have some information about potential gains that reasonably could be expected as a result of such investment.

**Juvenile Survival Improvement.** In Chapter 5, survival improvement targets were developed as a tool for comparing the potential benefits of implementing different management actions. This planning exercise used the best available information about estuary mortality for wild, ESA-listed stream- and ocean-type juveniles and then established a 20 percent survival improvement target for the 22 management actions that would affect the survival of juveniles. The survival improvement targets were then allocated across the various management actions to help characterize where survival gains might occur. The results are not intended to represent a deterministically based analysis; however, they do reflect information in the scientific literature, especially about mortality resulting from terns, cormorants, ship wake stranding, contaminants, and pinnipeds.

Tables 7-2 and 7-3 summarize the results of this planning exercise, sorting actions by their potential to improve survival of stream- and ocean-type juveniles, respectively, assuming that implementation of the actions is constrained. This ordering is simply an exercise to hypothesize where survival improvements equal to 20 percent of the number of juveniles exiting the estuary and plume might be expected for stream-type and ocean-type juveniles.

For stream-type salmonids, the following observations can be made from Table 7-2:

- Approximately 60 percent of the survival improvements are assigned to the top five actions, which include adjusting flow, protecting or restoring off-channel habitat, restoring or mitigating contaminated sites, and managing birds that prey on salmonids.
- Approximately 30 percent of the survival improvements are assigned to establishing or improving access to off-channel habitat, protecting and restoring riparian areas, reducing sources of pollutants, managing piscivorous fish, and removing or modifying pilings and pile dikes.
- Approximately 10 percent of the survival improvements are assigned across the remaining actions, with varying degrees of improvements.

For ocean-type salmonids, the following observations can be made from Table 7-3:

- Approximately 65 percent of the survival improvements are assigned to the top five actions, which include adjusting flows, establishing or improving access to off-channel habitat, protecting or restoring off-channel habitat, and addressing issues of contamination.
- Approximately 30 percent of the survival improvements are assigned to protecting and restoring riparian areas, reducing reservoir heating, removing or modifying pilings and pile dikes, reducing vessel wake stranding, using dredged materials beneficially,

managing piscivorous fish, and implementing pesticide, fertilizer, and stormwater BMPs.

- Approximately 5 percent of the survival improvements are assigned across the remaining actions, with varying degrees of improvements.

**Table 7-2**
Management Actions Sorted by Benefit to Stream-type Juveniles

| # | Action | Survival Target (Stream Types) | Percentage of Target Improvements |
|---|---|---|---|
| CRE-16 | Redistribute Caspian terns. | 350,000 | ~60% |
| CRE-17 | Redistribute cormorants. | 250,000 | |
| CRE-09 | Protect/restore high-quality off-channel habitat. | 150,000 | |
| CRE-22 | Restore or mitigate contaminated sites. | 142,000 | |
| CRE-04 | Adjust the timing, magnitude, and frequency of hydrosystem flows. | 125,000 | |
| CRE-13 | Manage pikeminnow and other piscivorous fish. | 122,000 | ~30% |
| CRE-10 | Breach, lower, or relocate dikes and levees. | 100,000 | |
| CRE-01 | Protect/restore riparian areas. | 100,000 | |
| CRE-08 | Remove or modify pilings and pile dikes | 100,000 | |
| CRE-21 | Identify and reduce sources of pollutants. | 72,000 | |
| CRE-20 | Implement pesticide/fertilizer BMPs. | 42,000 | ~10% |
| CRE-23 | Implement stormwater BMPs. | 30,000 | |
| CRE-02 | Operate the hydrosystem to reduce reservoir heating. | 20,000 | |
| CRE-03 | Protect/enhance instream flows influenced by water withdrawals and other water management actions in tributaries. | 20,000 | |
| CRE-06 | Use dredged materials beneficially. | 15,000 | |
| CRE-15 | Reduce invasive plants. | 15,000 | |
| CRE-07 | Reduce entrainment/habitat effects of dredging and ballast. | 10,000 | |
| CRE-05 | Mitigate entrapment of fine sediment in reservoirs. | 5,000 | |
| CRE-18 | Reduce shad abundance. | 5,000 | |
| CRE-11 | Reduce over-water structures. | 3,000 | |
| CRE-19 | Prevent aquatic invertebrate introductions. | 2,000 | |
| CRE-12 | Reduce vessel wake stranding. | 2,000 | |
| | **Total:** | 1.68 million | |

**TABLE 7-3**
Management Actions Sorted by Benefit to Ocean-type Juveniles

| # | Action | Survival Target (Ocean Types) | Percentage of Target Improvements |
|---|---|---|---|
| CRE-10 | Breach, lower, or relocate dikes and levees. | 450,000 | ~65% |
| CRE-09 | Protect/restore high-quality off-channel habitat. | 400,000 | |
| CRE-22 | Restore or mitigate contaminated sites. | 300,000 | |
| CRE-21 | Identify and reduce sources of pollutants. | 275,000 | |
| CRE-04 | Adjust the timing, magnitude, and frequency of hydrosystem flows. | 225,000 | |
| CRE-01 | Protect/restore riparian areas. | 150,000 | ~30% |
| CRE-08 | Remove or modify pilings and pile dikes | 150,000 | |
| CRE-13 | Manage pikeminnow and other piscivorous fish. | 140,000 | |
| CRE-02 | Operate the hydrosystem to reduce reservoir heating. | 90,000 | |
| CRE-23 | Implement stormwater BMPs. | 65,000 | |
| CRE-12 | Reduce vessel wake stranding. | 55,000 | |
| CRE-20 | Implement pesticide/fertilizer BMPs. | 50,000 | |
| CRE-06 | Use dredged materials beneficially | 50,000 | |
| CRE-03 | Protect/enhance instream flows influenced by water withdrawals and other water management actions in tributaries. | 25,000 | ~5% |
| CRE-11 | Reduce over-water structures. | 25,000 | |
| CRE-15 | Reduce invasive plants. | 20,000 | |
| CRE-07 | Reduce entrainment/habitat effects of dredging and ballast. | 8,000 | |
| CRE-19 | Prevent aquatic invertebrate introductions. | 8,000 | |
| CRE-05 | Mitigate entrapment of fine sediment in reservoirs. | 5,000 | |
| CRE-18 | Reduce shad abundance. | 5,000 | |
| CRE-16 | Redistribute Caspian terns. | 2,000 | |
| CRE-17 | Redistribute cormorants. | 2,000 | |
| | **Total:** | 2.5 million | |

While many of the actions are highly constrained, the planning exercise summarized in Tables 7-2 and 7-3 assumes that, even with incremental changes associated with constrained implementation, certain actions could yield significant results, especially when coupled with complementary actions. For example, ocean-type juveniles rely heavily on off-channel habitats for food sources and rearing opportunities. The two primary actions intended to improve access to off-channel habitats are CRE-10, "Breach, lower, or relocate dikes and levees," and CRE-4, "Adjust the timing, magnitude, and frequency of hydrosystem flows." Implementation of both of these actions is highly constrained, yet they could have synergistic effects and their joint implementation—even if only partial—could result in significant survival improvements for ocean-type salmonids. In contrast, if only one of these actions were implemented (or, worse yet, neither), other actions would need to be implemented as fully as possible in an attempt to compensate for the foregone opportunity to address one of the main factors limiting juvenile salmonid performance in the estuary.

**Adult Survival Improvement.** Because CRE-14, "Reduce predation by pinnipeds," is the only action that directly addresses the adult life history stage of salmonids, this action is treated separately and is not included in Tables 7-2 and 7-3. In 2010, which saw the largest spring Chinook and steelhead runs from 2002 to 2010, pinniped predation on spring Chinook and steelhead (both of which are stream types) at Bonneville Dam was estimated to be 2.2 percent. This equates to 6,081 spring Chinook and steelhead out of a run size of 267,194 fish (U.S. Army Corps of Engineers 2010). Projects to reduce pinniped predation have had limited success, and more stringent management techniques are constrained by protections afforded by the Marine Mammal Protection Act. Although the act does provide for lethal control, the process for implementing that provision is challenging. In 2008, NMFS granted authority under Section 120 of the Marine Mammal Protection Act to the states of Oregon, Washington, and Idaho to intentionally take, by lethal methods, individually identifiable California sea lions that prey on Pacific salmon and steelhead at Bonneville Dam, but the effectiveness of this approach is unknown. Given these constraints, PC Trask & Associates, Inc., in consultation with NMFS Northwest Regional Office staff, estimated that CRE-14 might result in a 17 percent reduction in pinniped-related mortality of adults at Bonneville Dam each year (approximately 1,034 fish annually as applied to 2010 run returns).

## Costs for Constrained Implementation of Management Actions

As discussed in Chapter 5, estimating the cost of the management actions in this module is inherently difficult and involves significant uncertainties. This is partly because in many cases, the constraints to implementation have not yet been explored in enough detail to be able to determine what is and is not possible, and key scientific and technical questions about the estuary have not yet been answered. In Chapter 5, Table 5-6 established cost estimates for constrained implementation of actions by assuming an optimistic view—that constraints can be reduced through focused effort and that positive changes in the estuary can be made. A more pessimistic view would likely yield a significantly lower cost estimate, with correspondingly smaller survival improvements. Costs were assigned at the project scale to help identify possible components to actions, with the expectation that future refinements would yield a more sophisticated estimate. Finally, project costs were estimated over a 25-year time horizon.

Table 7-4 organizes management actions by total estimated cost (from Table 5-6). The following observations can be made:

- Costs for the top six actions total $332 million, or about 63 percent of the entire budget. The actions include restoring contaminated sites, modifying flows, reducing sources of pollutants, establishing or improving access to off-channel habitats, protecting or restoring off-channel habitats, and protecting and restoring riparian areas.
- Costs for the next six actions on the list equal $108 million, or about 20 percent of the budget. This group of actions consists of reducing reservoir-related temperature changes, implementing stormwater BMPs, addressing vessel wake stranding, removing or modifying pilings and pile dikes, and managing fish and pinnipeds that prey on salmonids.
- The final 11 actions on the list equal $88 million, or about 17 percent of the budget.

**TABLE 7-4**
Management Actions Sorted by Estimated Cost

| # | Action | Cost of Action | Cost per Group of Actions |
|---|---|---|---|
| CRE-10 | Breach, lower, or relocate dikes and levees. | $75 million | ~$332 million, or 63% of total |
| CRE-09 | Protect/restore high-quality off-channel habitat. | $68 million | |
| CRE-22 | Restore or mitigate contaminated sites. | $60.5 million | |
| CRE-21 | Identify and reduce sources of pollutants. | $46 million | |
| CRE-04 | Adjust the timing, magnitude, and frequency of hydrosystem flows. | $44.5 million | |
| CRE-01 | Protect/restore riparian areas. | $38 million | |
| CRE-08 | Remove or modify pilings and pile dikes | $27.25 million | ~$108 million, or 20% of total |
| CRE-02 | Operate the hydrosystem to reduce reservoir heating. | $20 million | |
| CRE-23 | Implement stormwater BMPs. | $19.5 million | |
| CRE-14 | Reduce predation by pinnipeds. | $15 million | |
| CRE-13 | Manage pikeminnow and other piscivorous fish. | $13 million | |
| CRE-12 | Reduce vessel wake stranding. | $13 million | |
| CRE-15 | Reduce invasive plants. | $12.5 million | ~$88 million, or 17% of total |
| CRE-17 | Redistribute cormorants. | $10.5 million | |
| CRE-20 | Implement pesticide/fertilizer BMPs. | $12.5 million | |
| CRE-03 | Protect/enhance instream flows influenced by water withdrawals and other water management actions in tributaries. | $10 million | |
| CRE-16 | Redistribute Caspian terns. | $10 million | |
| CRE-05 | Mitigate entrapment of fine sediment in reservoirs. | $8 million | |
| CRE-06 | Use dredged materials beneficially. | $6 million | |
| CRE-11 | Reduce over-water structures. | $5.8 million | |
| CRE-18 | Reduce shad abundance. | $5.5 million | |
| CRE-07 | Reduce entrainment/habitat effects of dredging and ballast. | $4.5 million | |
| CRE-19 | Prevent aquatic invertebrate introductions. | $3 million | |
| | **Total:** | $528.05 million | |

As also discussed in Chapter 5, there is significant uncertainty in these cost estimates because of the ambiguity about the degree to which constraints to implementation can be overcome, the level of effort that would be required to achieve a measurable result, and how new information could change current understanding about the cost and effectiveness of management actions. However, it is assumed that if restoring the ecosystem of the Columbia River estuary were established as a goal, this would require financial investment on a par with that for other major ecosystem recovery efforts around the United States.

## Cost-Effectiveness of Management Actions

Cost-effectiveness is an important consideration when attempting to achieve large goals with limited resources, and the more limited the resources with respect to the goal, the more important it is that the maximum benefit be obtained from each expenditure. In the case of the Columbia River estuary, improving conditions for salmonids is likely to be an expensive and long-term effort—one that will require careful consideration of the survival benefits and costs of possible actions.

The linkage between the survival benefits and costs in this recovery plan module is difficult to characterize accurately because of the margin of error that, at this point, exists in both the estimated costs and the survival targets. Because the survival improvement targets were allocated across the set of actions as a planning exercise rather than as results of a scientific analysis, it is the allocation that is most important, not the target numbers themselves. In the case of costs, estimates were made assuming that constraints to implementation of actions could be partially overcome; this assumption served as a way to explore the degree of constraints and the level of effort that would be required to bring about significant benefits to salmonids. The resulting costs should be viewed as preliminary numbers useful in starting critical discussions about decisions that will shape the future of the estuary.

Understanding that, as outlined above, there are limitations governing the survival improvement targets and cost estimates, these sets of numbers can be compared to provide clues about which management actions might be the most cost-effective. Table 7-5 makes such a comparison, using cost information from Table 7-4 and target survival improvements from Table 7-3 to estimate the cost-effectiveness of each action, expressed as a cost/survival index. The actions are sorted in ascending order to show the most cost-effective actions first.

Table 7-5 is intended as a general indication of cost-effectiveness to help frame the discussion about implementing management actions. Also, some actions were assigned very conservative survival improvement numbers because of the level of uncertainty about underlying ecological processes. This is the case with several actions related to the food web because the connection between food web changes and effects on juveniles is not fully defined. As a result, the cost-effectiveness ratings of these actions appear high.

**TABLE 7-5**
Management Actions Sorted by Cost/Survival Index

| # | Action | Survival (Ocean Types) | Survival (Stream Types) | Total Survival | Cost of Action | Cost/ Survival Index |
|---|---|---|---|---|---|---|
| CRE-16 | Redistribute Caspian terns. | 2,000 | 350,000 | 352,000 | $10 million | 28 |
| CRE-17 | Redistribute cormorants. | 2,000 | 250,000 | 252,000 | $10.5 million | 42 |
| CRE-13 | Manage pikeminnow and other piscivorous fish. | 140,000 | 122,000 | 262,000 | $13 million | 50 |
| CRE-06 | Use dredged materials beneficially. | 50,000 | 15,000 | 65,000 | $6 million | 92 |
| CRE-08 | Remove or modify pilings and pile dikes | 150,000 | 100,000 | 250,000 | $27.25 million | 109 |
| CRE-09 | Protect/restore high-quality off-channel habitat. | 400,000 | 150,000 | 550,000 | $68 million | 124 |
| CRE-04 | Adjust the timing, magnitude, and frequency of hydrosystem flows. | 225,000 | 125,000 | 350,000 | $44.5 million | 127 |
| CRE-21 | Identify and reduce sources of pollutants. | 275,000 | 72,000 | 347,000 | $46 million | 133 |
| CRE-20 | Implement pesticide/fertilizer BMPs. | 50,000 | 42,000 | 92,000 | $12.5 million | 136 |
| CRE-10 | Breach, lower, or relocate dikes and levees. | 450,000 | 100,000 | 550,000 | $75 million | 136 |
| CRE-22 | Restore or mitigate contaminated sites. | 300,000 | 142,000 | 442,000 | $60.5 million | 137 |
| CRE-01 | Protect/restore riparian areas. | 150,000 | 100,000 | 250,000 | $38 million | 152 |
| CRE-02 | Operate the hydrosystem to reduce reservoir heating. | 90,000 | 20,000 | 110,000 | $20 million | 182 |
| CRE-23 | Implement stormwater BMPs. | 65,000 | 30,000 | 95,000 | $19.5 million | 205 |
| CRE-11 | Reduce over-water structures. | 25,000 | 3,000 | 28,000 | $5.8 million | 207 |
| CRE-03 | Protect/enhance instream flows influenced by water withdrawals and other water management actions in tributaries. | 25,000 | 20,000 | 45,000 | $10 million | 222 |
| CRE-12 | Reduce vessel wake stranding. | 55,000 | 2,000 | 57,000 | $13 million | 228 |
| CRE-07 | Reduce entrainment/habitat effects of dredging and ballast. | 8,000 | 10,000 | 18,000 | $4.5 million | 250 |
| CRE-19 | Prevent aquatic invertebrate introductions. | 8,000 | 2,000 | 10,000 | $3 million | 300 |
| CRE-15 | Reduce invasive plants. | 20,000 | 15,000 | 35,000 | $12.5 million | 357 |
| CRE-18 | Reduce shad abundance. | 5,000 | 5,000 | 10,000 | $5.5 million | 550 |
| CRE-05 | Mitigate entrapment of fine sediment in reservoirs. | 5,000 | 5,000 | 10,000 | $8 million | 800 |

The following observations can be made from Table 7-5:

- The median of all assigned cost/survival index numbers is 144. (The median is the middle number of a group of numbers, with half the numbers having values greater than the median and half having values less than the median).
- Some of the actions that appeared most cost-prohibitive in Table 7-4, such as establishing or improving access to off-channel habitat (CRE-10), adjusting flows (CRE-04), and restoring or mitigating contaminated sites (CRE-22), emerge as cost-effective when viewed in the context of the survival improvements they could bring about. All three of these actions have a cost/survival index value that is less than the median and that puts them in the top—or more cost-effective—half of Table 7-5.
- Several actions, including redistributing terns (CRE-16), redistributing cormorants (CRE-17), and managing piscivorous fish such as pikeminnow (CRE-13), appear to be very cost-effective.

In this planning exercise, the total survival improvement of actions listed above the median is 3.5 million juveniles (2.0 million ocean type and 1.5 million stream type), or about 17 percent of the total number of juveniles currently thought to be exiting the estuary.

# Improving Ecosystem Health

The Columbia River estuary and plume ecosystems are degraded compared to historical conditions. One hypothesis of this recovery plan module is that if the estuary and plume remain in their degraded state, recovery of all 13 ESUs may not be possible. The remainder of this section is intended to help characterize choices that will ultimately govern the health of the estuarine ecosystem in the Columbia River.

**Is there really a problem for salmonids in the estuary?** Sources such as *Salmon at River's End* (Bottom et al. 2005), and emerging micro-acoustic tagging studies make clear that the mortality rate in the estuary is very high and almost certainly approaches 50 percent for some ESUs. This alone argues for discarding the old paradigm of the estuary as primarily a transportation corridor for salmonids on their journey to the ocean. Stream- and ocean-type salmonids clearly rely on estuary and plume habitats for crucial rearing and refuge opportunities during one of the stages in their life cycles. Chapters 3 and 4 of this estuary recovery module describe the mechanisms by which a degraded estuarine ecosystem puts juvenile salmonids at risk.

**Is ecosystem restoration necessary in the estuary, or can we surgically reduce specific threats to improve salmonid survival?** Ecosystem health in the estuary and plume is the cumulative result of many stressors that originate within the estuary and also outside of the estuary. The level of constraint observed in each of the management actions identified in this estuary recovery module is high, and it is extremely unlikely that one or more actions could be implemented to the degree that they would essentially eliminate a threat to salmonids. Thus each management action should be implemented to the greatest degree practical, unless it is proven that to do so would seriously undermine public safety, the economy, or property rights.

**What suite of actions is most important to implement for ocean-type salmonids?** There is no single correct answer to this question. In the long term, ecosystem restoration will provide the most stable, self-supporting conditions for salmonids and other native species. Ocean-type juvenile salmonids rear longer in the estuary than stream types do and therefore would benefit the most from improved ecosystem health.

The analysis and planning exercises in this recovery plan module suggest that the following actions are most important for ocean-type salmonids:

- CRE-01: Protect/restore riparian areas.
- CRE-02: Operate the hydrosystem to reduce reservoir heating.
- CRE-04: Adjust the timing, magnitude, and frequency of hydrosystem flows.
- CRE-08: Remove or modify pilings and pile dikes.
- CRE-09: Protect/restore high-quality off-channel habitat.
- CRE-10: Breach, lower, or relocate dikes and levees.
- CRE-13: Manage pikeminnow and other piscivorous fish.
- CRE-21: Identify and reduce sources of pollutants.
- CRE-22: Restore or mitigate contaminated sites.

Implementing this suite of actions would cost approximately $392.3 million and would be expected to yield survival improvements of roughly 2.2 million wild, ESA-listed ocean-type juveniles, or 88 percent of the survival target for ocean-type salmonids. In other words, for ocean-type juveniles, 88 percent of the gain to be had from the management actions could be achieved by implementing these nine actions.

**What suite of actions is most important to implement for stream-type salmonids?** Stream-type salmonids prefer deeper waters with higher velocities than ocean-types do. They also reside in the estuary for shorter periods of time, but they tend to use the plume more extensively than do ocean-type salmonids. Stream-type juveniles are thought to actively feed in the estuary; information indicates that stream types travel out of the channel to forage and may encounter predators such as the northern pikeminnow (Casillas 2006). For stream types, it is very important to reduce Caspian tern and double-crested cormorant predation. In addition, predation by pinnipeds on adult spring Chinook and winter steelhead is a significant threat.

The analysis and planning exercises in this recovery plan module suggest that the following actions are most important for stream-type salmonids:

- CRE-01: Protect/restore riparian areas.
- CRE-04: Adjust the timing, magnitude, and frequency of hydrosystem flows.
- CRE-08: Remove or modify pilings and pile dikes.
- CRE-09: Protect/restore high-quality off-channel habitat.
- CRE-10: Breach, lower, or relocate dikes and levees.
- CRE-13: Manage pikeminnow and other piscivorous fish.
- CRE-14: Reduce predation by pinnipeds.
- CRE-16: Redistribute Caspian terns.
- CRE-17: Redistribute cormorants.
- CRE-21: Identify and reduce sources of pollutants.
- CRE-22: Restore or mitigate contaminated sites.

Implementing this suite of actions would cost approximately $407.8 million and would be expected to yield survival improvements of roughly 5,000 stream-type adults (ESA-listed and non-listed adults) and 1.51 million wild, ESA-listed stream-type juveniles, or 90 percent of the survival target for stream-type juveniles. In other words, for stream-type juveniles, 90 percent of the gain to be had from the management actions could be achieved by implementing these 11 actions.

**How cost-effective are the top actions for ocean- and stream-type salmonids?** Of the top 11 priority actions for stream- and ocean-type salmonids, nine are listed at or above the median cost/survival index.

**What would be gained by implementing actions that benefit both ocean- and stream-type salmonids?** The lists of priority actions identified above for ocean- and stream-type salmonids contain eight actions that are predicted to benefit both types of salmonids. These actions are as follows:

- CRE-01: Protect/restore riparian areas.
- CRE-04: Adjust the timing, magnitude, and frequency of hydrosystem flows.
- CRE-08: Remove or modify pilings and pile dikes.
- CRE-09: Protect/restore remaining high-quality off-channel habitat.
- CRE-10: Breach, lower, or relocate dikes and levees.
- CRE-13: Manage pikeminnow and other piscivorous fish.
- CRE-21: Identify and reduce sources of pollutants.
- CRE-22: Restore or mitigate contaminated sites.

Implementing this set of actions would cost approximately $372.25 million and would be expected to yield survival improvements of roughly 3 million wild, ESA-listed juvenile salmonids (ocean- and stream-types combined). Although the majority of these would be ocean types, there is an argument to be made for favoring actions that would benefit both salmonid types—namely, that implementing such actions would be likely to provide benefits across the spectrum of life history strategies that juvenile salmonids of both types employ in the estuary. Many of the actions that benefit stream-type salmonids would also benefit ocean types displaying less dominant life history strategies, while many actions benefiting ocean-type salmonids would also benefit stream types displaying less dominant life history strategies. Actions that benefit both ocean and stream types, then, presumably would affect a wide range of less dominant life history strategies and thus would help preserve the diversity that contributes to salmonids' ability to persist in the face of changing environmental conditions.

However, this is not to suggest implementation only of those actions that would benefit both ocean- and stream-type juveniles because there are limitations to this approach. For instance, avian and pinniped predation actions, which would primarily benefit stream types, are cost-effective and critical to improving the survival of stream-type salmonids.

**Will management actions have synergistic effects?** Many of the management actions could have far-reaching effects if they were implemented together, either because they address multiple interrelated threats, such as flow regulation and impaired sediment transport, or because their effects could amplify the benefits of other, complementary management actions. An example would be the two actions of improving flows and establishing access to off-channel habitat by breaching dikes or levees. Although each action by itself would

increase salmonid access to off-channel habitat, implementing both actions has the potential to offer exponentially greater access, as well as contribute macrodetrital inputs to the food web and offer other ecosystem benefits. Although such benefits are difficult to quantify, the potential for synergistic effects of complementary actions is real and should be taken into consideration when management actions are selected.

The U.S. Army Corps of Engineers currently is studying the cumulative effects of various combinations of restoration activities in the estuary; results of the study are expected to provide valuable data on the potential synergistic effects of the management actions presented in the estuary recovery plan module. Meanwhile, several actions have the potential to be complementary in their effects, at the very least, and possibly to offer significant synergistic benefits. While it is not possible to identify all such actions, examples include using dredged materials to reduce vessel wake stranding (CRE-6 and CRE-12) or improving access to off-channel habitats by breaching dikes and adjusting flows (CRE-10 and CRE-4). At the same time, management actions need to be sequenced to avoid possible negative synergistic effects, such as by restoring contaminated sites (CRE-22) in off-channel habitat before restoring access to that habitat through dike breaching and flow modifications (CRE-10 and CRE-4). Considering the possible complementary, cumulative, or synergistic effects of management actions and sequencing actions for maximum benefit will be important aspects of implementing the estuary recovery plan module.

**What about the lower ranking actions?** In many ways, the lower ranking actions are the most difficult to characterize in terms of survival improvements and costs. Low ratings may be due more to a lack of scientific information than a lack of effectiveness. For example, basic changes to the food web in the estuary as a result of increased phytoplankton production or the introduction of aquatic invertebrates may have profound effects on the estuary, but the degree of impact is unknown. These threats must be more fully understood if their contribution to overall ecosystem health is to be determined with accuracy.

**What planning tasks remain?** The process of developing this estuary recovery plan module pointed to several areas where recovery planning for the estuary could be refined. Additional scientific information about juvenile mortality in the estuary would clarify the ecological significance of the estuary relative to tributaries and the middle and upper mainstem Columbia River. A finer scale analysis of limiting factors, threats, and the benefits of management actions would aid in prioritizing actions and focusing them in the geographical areas where they would be most beneficial. Testing the assumptions underlying the allocation of benefits across management actions would increase the value of survival improvement targets as a planning tool, as would further evaluation of the constraints to implementation of the management actions. Lastly, understanding the potential cumulative or synergistic effects of management actions could lead to implementation decisions that would enhance the benefits of actions. Obtaining more information about these topics—mortality in the estuary, biological effects at a finer level, potential benefits of management actions, and synergistic effects—could represent the next level of planning for salmon recovery in the estuary.

## Implementation Issues

Implementation of the 23 actions in the module will require the efforts of a variety of Federal, state, and local agencies, organizations, private enterprises, and citizens. (Some potential implementers have been identified in Table 5-6.) While many of these entities have already been working to identify, prioritize, and implement salmon and steelhead recovery actions, effective implementation of all module actions will require additional coordination.

Goals of coordination include using existing processes, programs, and forums efficiently; ensuring the appropriate scale, scope, and sequencing of projects; coordinating funding; tracking and reporting on implementation progress; coordinating monitoring efforts; and providing data management. In addition, implementing the module will require further evaluation of the constraints associated with the 23 actions as well as consideration of potential cumulative and synergistic effects. Also, implementers of module actions will need to remain abreast of current scientific information and ensure that it is continually incorporated into implementation decisions. Although some elements of these larger processes are in place, additional organizational capacity is necessary if these needs are to be adequately addressed.

Table 5-6 includes a rudimentary schedule for implementing each of the 23 management actions described in Chapter 5, but this schedule will need to be refined as the considerations mentioned above are addressed. The first step in coordinated implementation of the module will be a conversation among all relevant entities and stakeholders to discuss near-term implementation priorities, with a goal of developing a 5-year implementation plan that provides specificity and certainty regarding near-term actions and that identifies lead entities for implementation of specific actions or projects. Given the complexities involved in implementing the full suite of module actions, this conversation also will be an opportunity to explore options for and recommend an organizational structure for coordinating and overseeing implementation of the module. The Lower Columbia River Estuary Partnership, a National Estuary Program established to bring about collaboration, would be an appropriate convener of this discussion.

Education and outreach are important aspects of module implementation. Threats to salmonids in the estuary are likely to continue unabated unless resource users in the Columbia River basin make different choices about consumption and development—choices that may be socially and politically challenging. In the face of social and political obstacles, education is one way of garnering support for implementation of the management actions; in fact, education about stewardship and the ecosystem benefits that implementation would provide is an essential component of the management actions in the module; to the extent possible, these education efforts should be coordinated to create efficiencies.

## Relationship of the FCRPS BiOp to the Estuary Module

Drafts of this module were available during the Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp) remand collaborative process, which led to the 2008-2018 FCRPS Biological Opinion and Supplemental Comprehensive Analysis (National Marine Fisheries Service 2008a and 2008b). Among the provisions of the 2008 FCRPS Biological Opinion (2008 BiOp) were requirements for the Federal action agencies to

implement habitat improvement and predation control actions in the estuary. Estimates of the survival benefits that would be gained from those actions were included in the 2008 BiOp, and those survival estimates were derived from the allocation of survival improvements among actions in this module.

In February 2010, NMFS issued the 2010 Supplemental BiOp for the FCRPS (National Marine Fisheries Service 2010), which integrated elements from the 2008 BiOp and Adaptive Management Implementation Plan (AMIP). The AMIP included accelerated and enhanced actions to protect Columbia Basin salmon and steelhead, including (1) commitments to additional estuary actions under an agreement with the state of Washington, and (2) efforts to control native predators and invasive species. The AMIP also included enhanced research and monitoring and incorporated specific biological triggers for contingencies linked to unexpected declines in the abundance of listed fish.

The 2010 Supplemental BiOp retained the estimates of survival improvements from estuary habitat and predation control actions that had been incorporated into the 2008 BiOp and that were based on a draft version of this estuary module. The 2010 Supplemental BiOp also summarized and assessed relevant new information that had become available since the 2008 BiOp was issued, including information on climate change, juvenile salmonid use of the estuary and plume, predation, toxics, and ecological interactions between hatchery- and natural-origin fish. The new information summarized in the 2010 BiOp will be useful in informing implementation decisions regarding actions in the module.

Actions in the 2008 BiOp and its 2010 Supplement that relate to estuarine habitat, predation, and flow will contribute to implementation of actions in this module. The module, however, identifies habitat, predation, and flow actions that are larger in scope than the actions that will be implemented under the 2008 BiOp and its 2010 Supplement. NMFS projects that the 2008 BiOp actions related to estuarine habitat, flow, and predation will yield only a portion of the total survival improvements that the estuary module hypothesizes are possible for actions in those categories. The intent of the estuary module was to lay out the full suite of limiting factors and threats affecting the estuary; to identify actions or assessments needed to address—or inform the potential to address—those limiting factors and threats; and to provide a basis for future discussions and societal decisions about recovery efforts in the Columbia River estuary.

# Preparation for Decision Making

Chapter 7 is intended to help organize a much-needed conversation about recovery efforts in the estuary, plume, and other ecosystems that salmonids depend on to complete their life cycles. While there are many decisions to be made, perhaps the most important is what our level of effort and commitment will be to improving conditions in the estuary. This boils down to deciding how much we are willing to do to recover salmon and steelhead in the Columbia River basin and how comfortable we are with the sacrifices that will be necessary.

The planning exercises in Chapters 5 and 7 were based on the best available science pertaining to limiting factors and threats. However, although science can help inform the key analyses in these chapters (the identification of management actions, constraints evaluation, survival improvement targets, and cost estimates), it cannot tell us which management actions to implement. This is so partly because of the gaps in our understanding of the physical and biological world of the estuary but also because other

decision-making processes come into play when we make choices about the future and what we most value. Ultimately, the degree to which the estuary module is implemented will be determined by the social and political will of the region, and what current and future residents of the basin are willing to pay for—or do without—in order to return salmon and steelhead to viable levels.

Perhaps the single most important conclusion that can be made about the prioritization of management actions is that threats remain threats to salmonids because tough choices have yet to be made—choices that are difficult because of the myriad conflicting goals of the various public, private, individual, and organizational interests within the Columbia River basin. The variety and extent of those interests are reflected in the high degree of constraint for each of the 23 management actions identified in the recovery plan module. The take-home message from this is that the estuary and plume are crucial to ocean- and stream-type salmonids and that achieving a meaningful boost in survival from these ecosystems will require a major investment and implementation of all 23 management actions, to the extent possible.

CHAPTER 8

# References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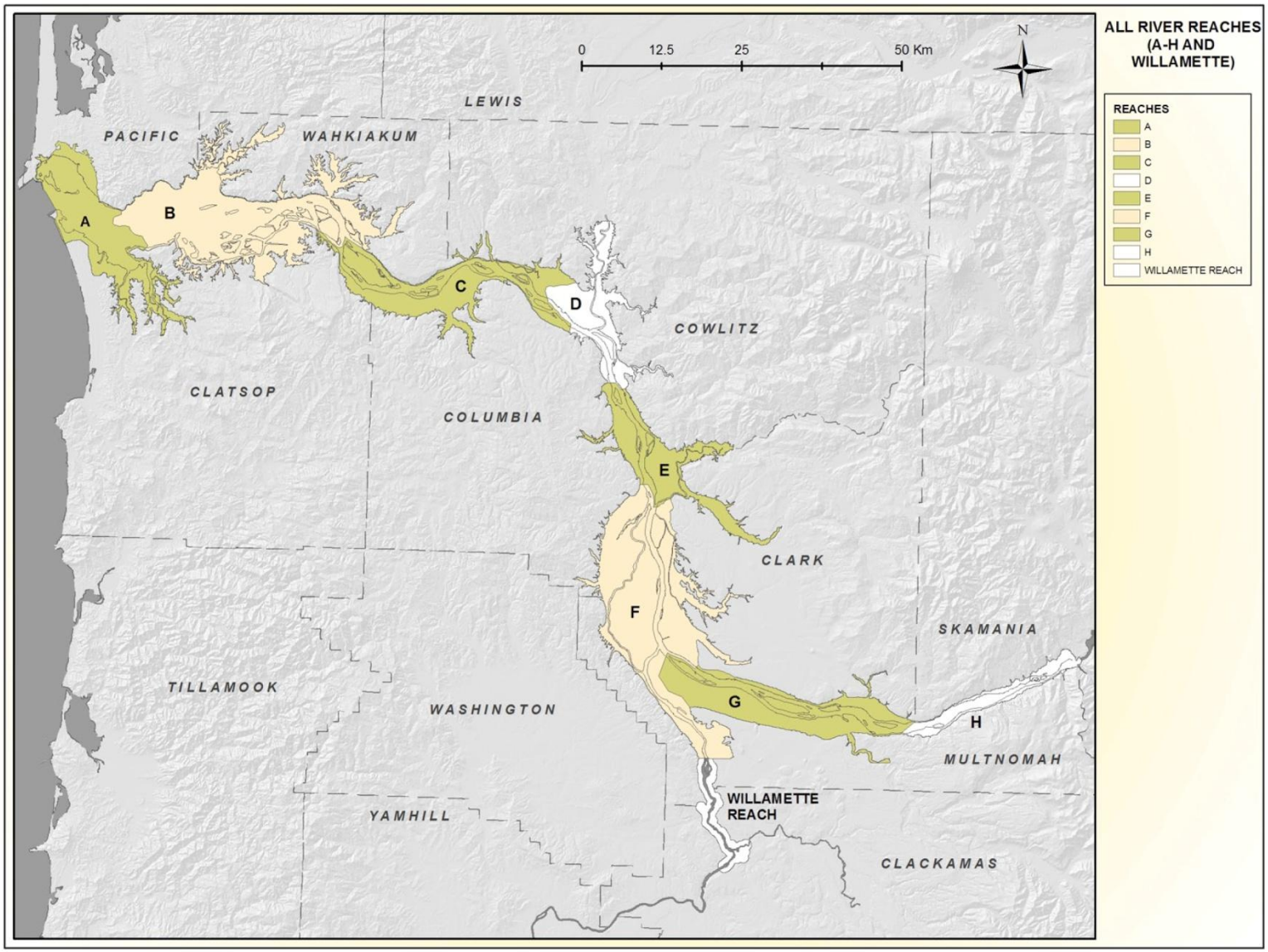
APPENDIX A

# Selected Threats to Salmonids by Reach

APPENDIX A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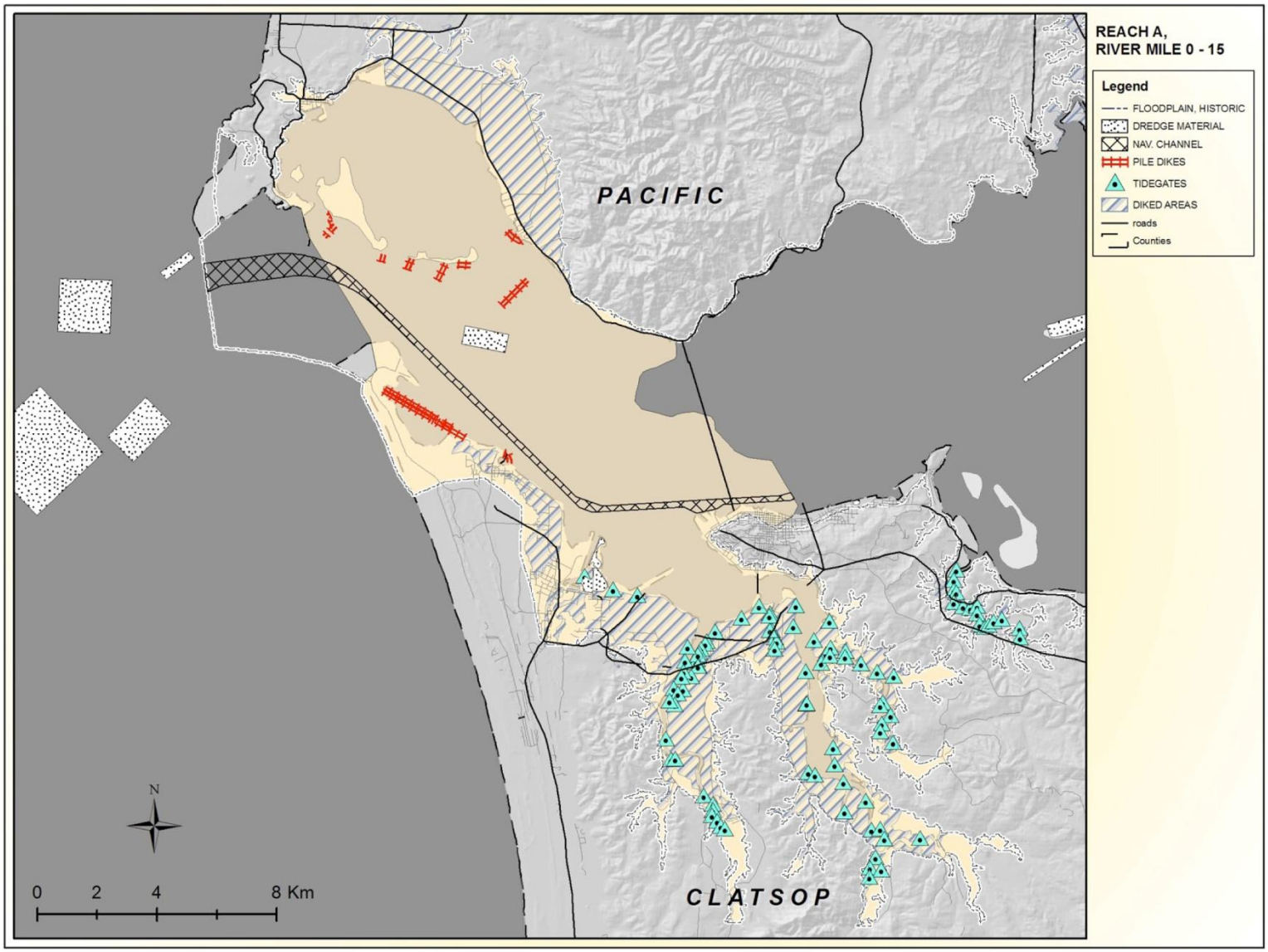
APPENDIX A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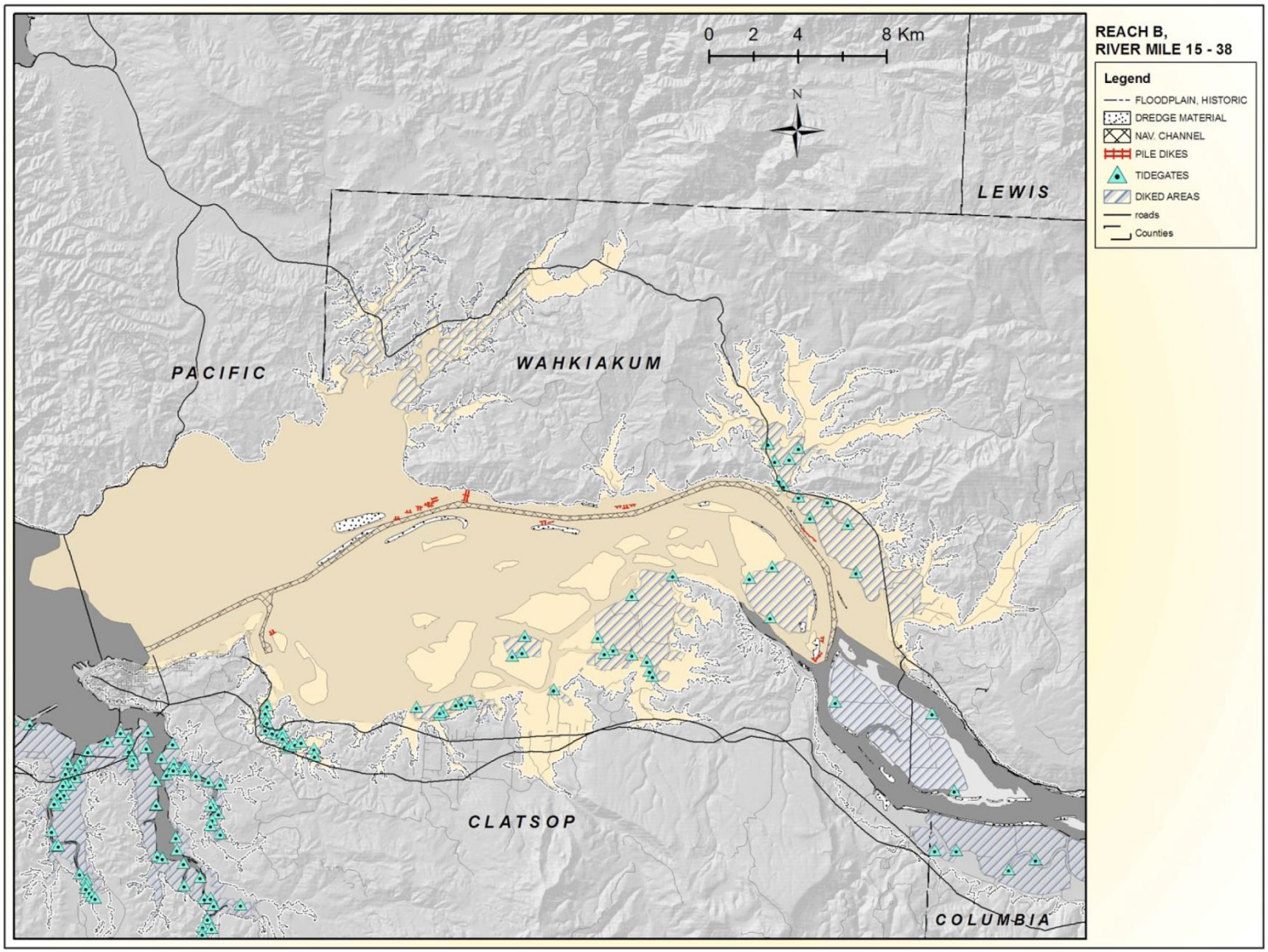
APPENDIX A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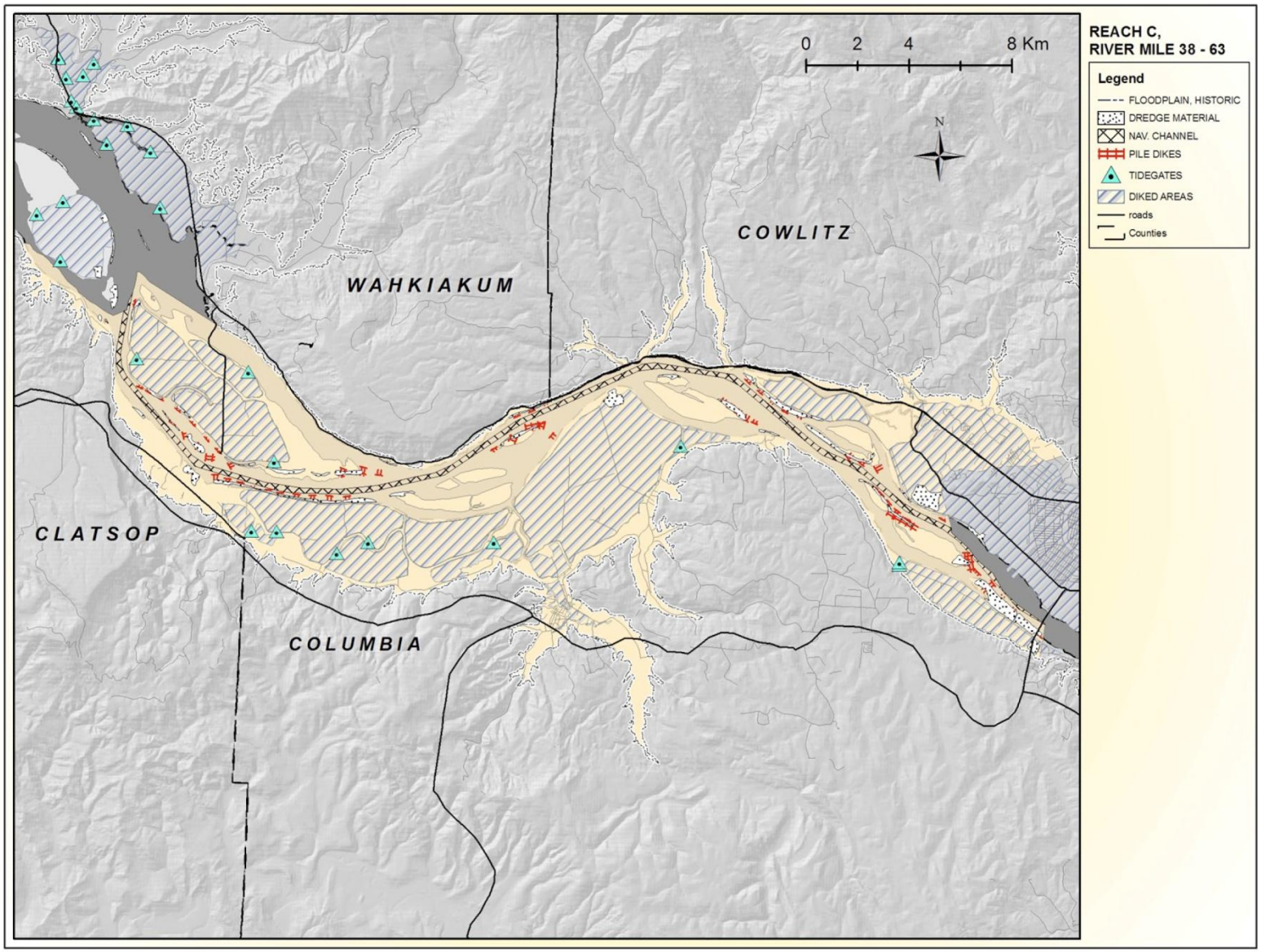
APPENDIX A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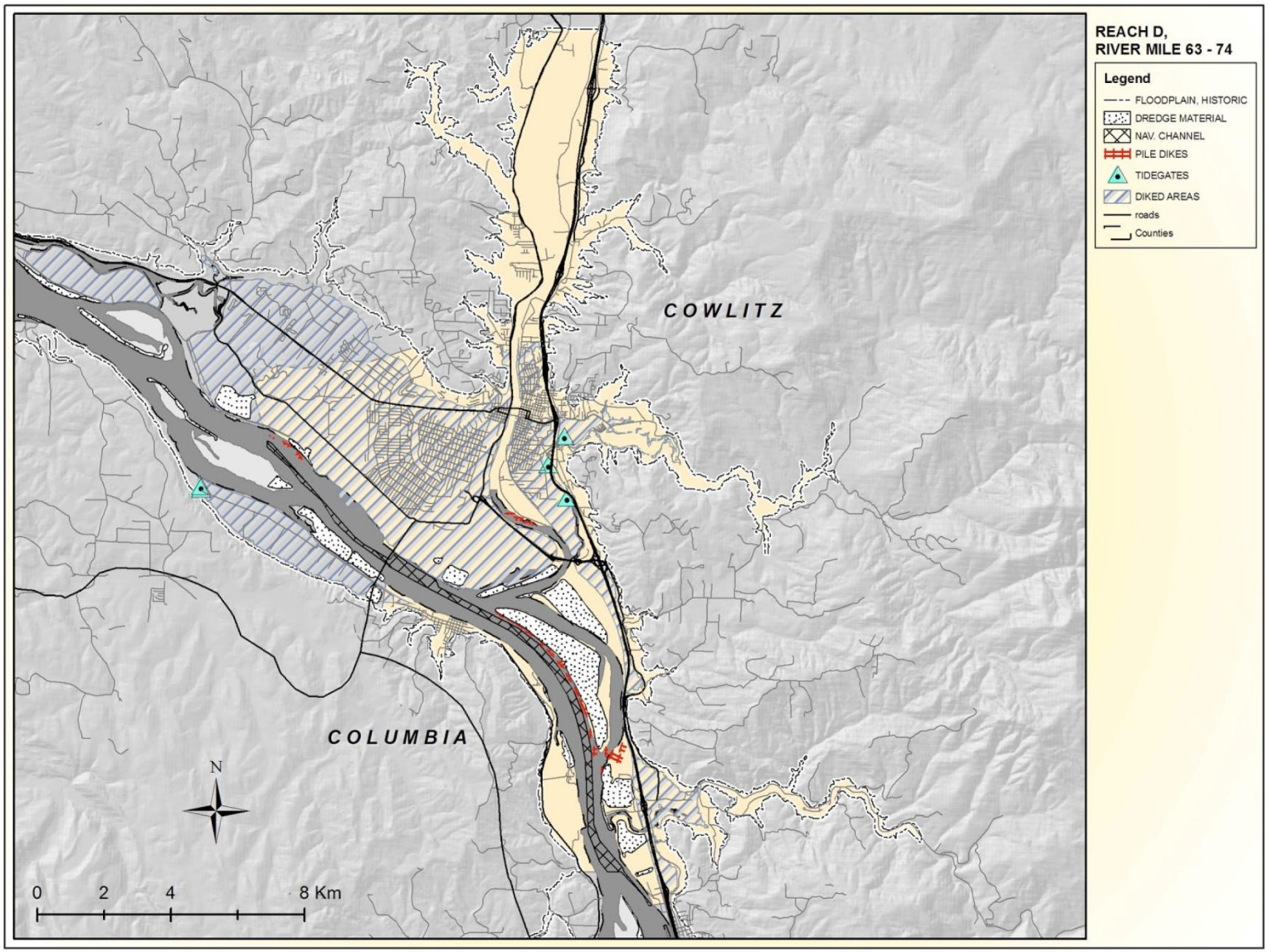
APPENDIX A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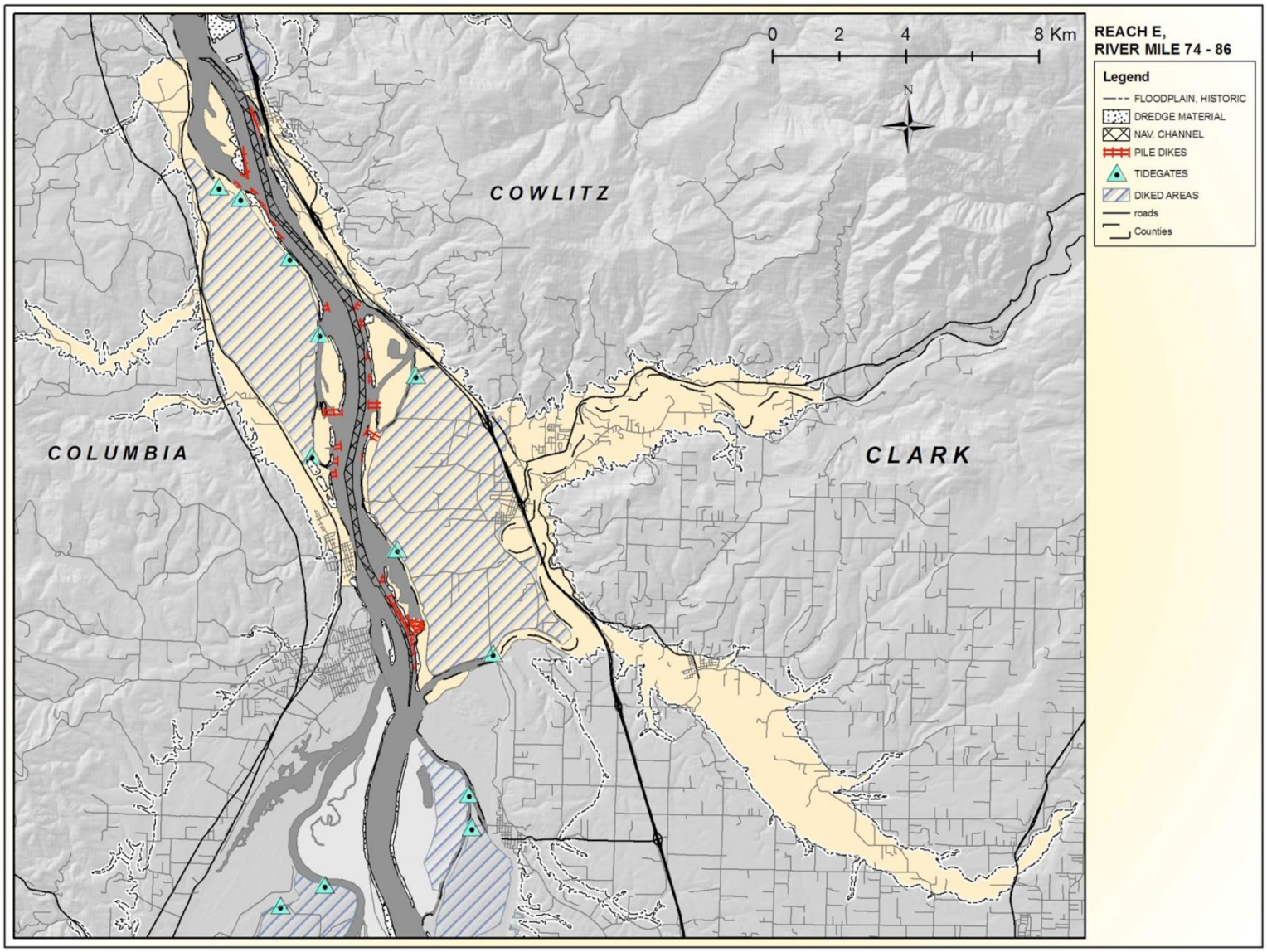
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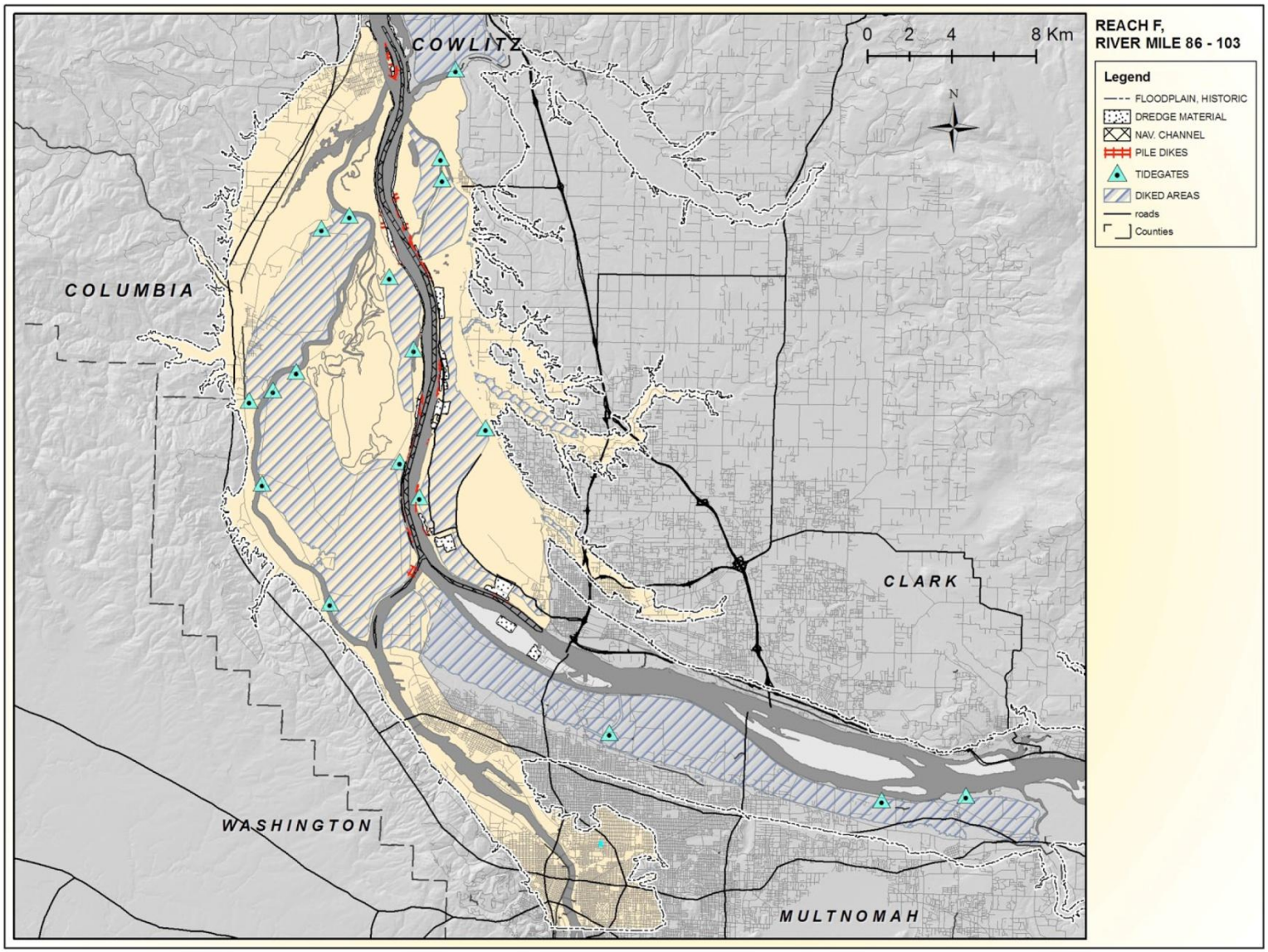
APPENDIX A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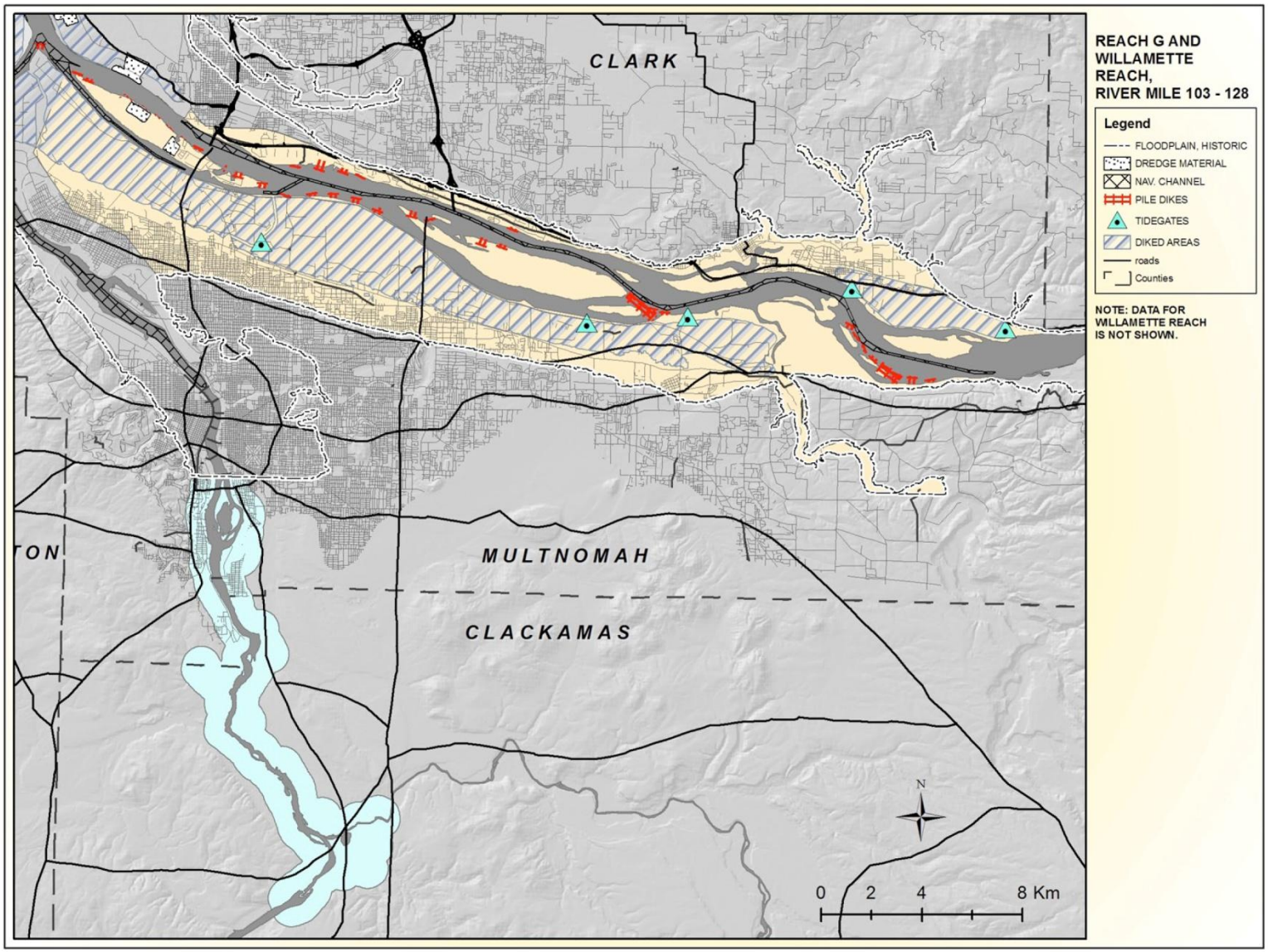
APPENDIX A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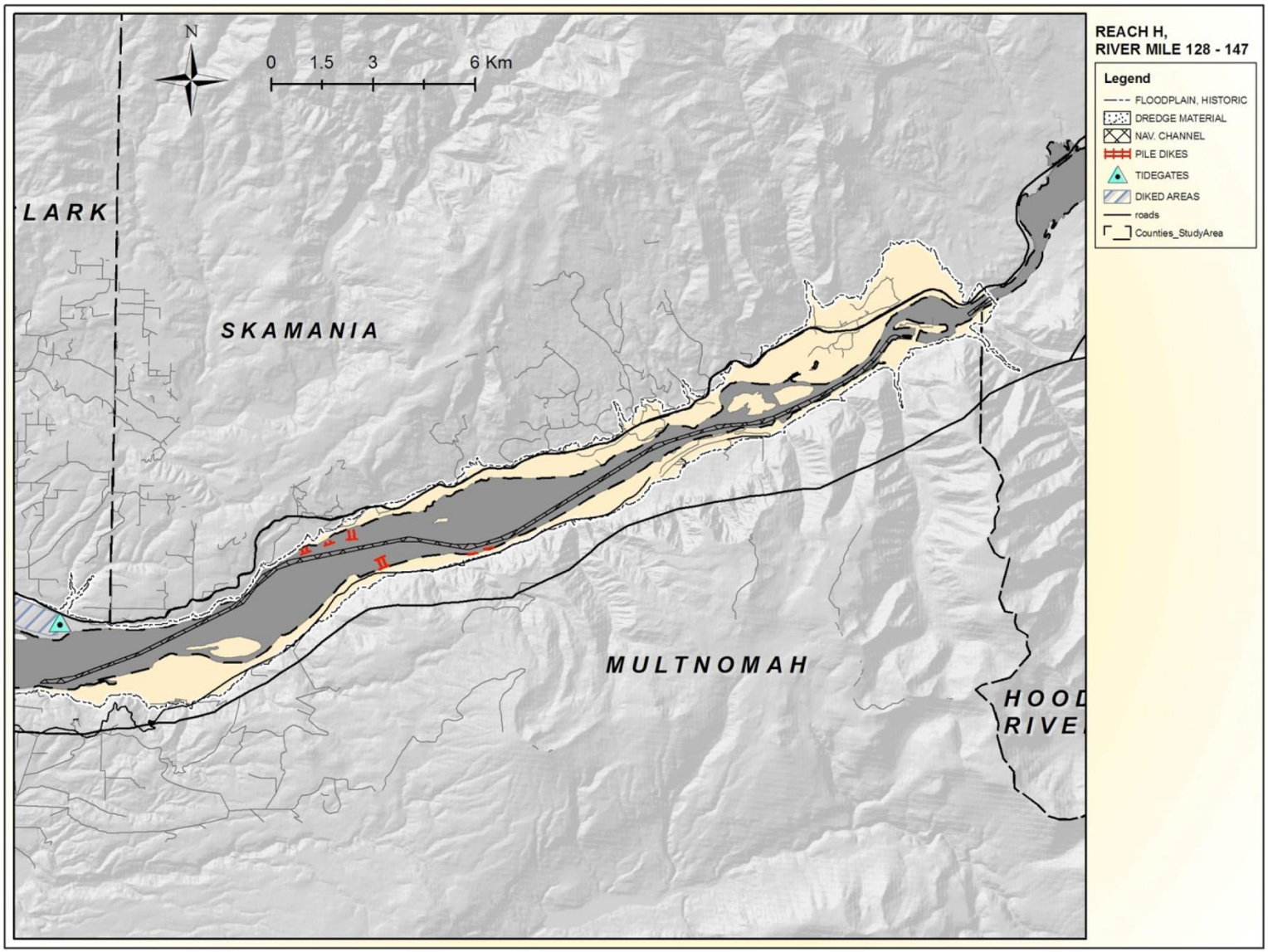
APPENDIX A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APPENDIX A

APPENDIX B

# Development of Survival Improvement Targets

APPENDIX B

# Development of Survival Improvement Targets

The survival improvement targets in Table 5-5 are a planning tool intended to help initiate a comprehensive discussion about salmonid mortality in the estuary and plume. This tool is an important first step in setting recovery targets for salmonids in the estuary and also for the Columbia River basin. PC Trask & Associates, Inc., developed the survival improvement targets because, in many cases, estimates of mortality resulting from individual limiting factors and of the effectiveness of management actions in reducing threats and limiting factors do not exist. On the other hand, there are reliable estimates of mortality resulting from several of the predators, ship wake stranding, and toxic contamination, and emerging acoustic wire tagging studies are helping to estimate the extent of mortality that juvenile salmonids experience during residency in the estuary.

PC Trask & Associates, Inc., took the following steps to develop the survival improvement targets:

1. Determined the abundance of wild, ESA-listed ocean- and stream-type juveniles entering the estuary using Ferguson (2006b), which estimated 25 million ocean-type juveniles and 14.3 million stream-type juveniles for 2006.

2. Assumed a 50 percent overall juvenile mortality rate for ocean-type salmonids in the estuary and a 40 percent mortality rate for stream-type juveniles. PC Trask & Associates, Inc., reached the 50 percent mortality estimate for ocean type juveniles by taking the 35 percent rate from 2005 micro-acoustic tagging results (Ferguson 2006b) and adding an additional 15 percent to account for smaller ocean-type juveniles not tracked by the study. PC Trask & Associates, Inc., reached the 40 percent mortality estimate for stream-type juveniles by taking the 25 percent rate from the same micro-acoustic tagging study and adding 15 percent to account for presumed deaths occurring in the plume. Continued annual study results will help refine these estimates over time.

3. Used a survival improvement target of 20 percent for both ocean- and stream-type juveniles. The 20 percent number is not scientifically based; instead, it represents a planning target that will require refinement as the extent to which actions are implemented and effective becomes clearer. Survival improvement numbers attempt to reflect wild, ESA-listed fish only. In most cases, known mortality to salmonids (such as from terns) does not break out wild fish from hatchery fish or ESA-listed fish from non-listed fish.

4. Allocated the two targets described above across 22 actions (CRE-14, "Reduce predation by pinnipeds," was treated separately for adult mortality), based on an extensive literature review and personal communication with various agency staff. PC Trask & Associates, Inc., evaluated each action using limiting factor information from Chapter 3, threat information from Chapter 4, and action evaluations from Chapter 5. As a result, the allocation takes into consideration a combination of factors, including the magnitude of the limiting factor, the degree of the associated threat(s), how well the action

addresses the threat, how constrained implementation of the action is likely to be, and the assumption that a considerable level of effort will be applied to implementing each action.

5. Assigned survival improvement targets on a relative scale across all of the actions. The reader should not view the survival improvement targets as an absolute numerical result for each action, but rather a relative indication of the importance of each action. In cases where the scientific community has determined the mortality associated with a particular limiting factor and developed a management plan with mortality reduction goals, such as with predation by Caspian terns, PC Trask & Associates, Inc., used these numbers to the degree possible.

Survival improvement targets are intended to be correlated with cost estimates presented in Table 5-6 for constrained implementation of the management actions. The resulting cost/survival estimates (see Table 7-5) are intended to initiate discussions about the validity of cost estimates and potential survival improvement targets; the cost/survival index values in Table 7-5 are highly uncertain because of the gross assumptions on both sides of the equation.

**Disclaimer:** Survival improvement numbers are for illustration only and are intended to demonstrate social choices in the face of significant uncertainty. Literature sources generally do not prescribe actions, and relatively few actions have been specifically evaluated for associated survival estimates.

Table B-1
Notes on Development of Survival Improvement Targets

| Action | Notes |
|---|---|
| CRE-1: Protect/restore riparian areas. | Estimate is unsupported in the literature.<br>Estimate was assigned a high value in recognition of its importance relative to food sources and shoreline habitats.<br>This is a protection action that is intended to reduce the potential for increased threat over time. |
| CRE-2: Operate the hydrosystem to reduce reservoir heating. | Estimate is unsupported in the literature.<br>Estimate was assigned a relatively high value because temperatures commonly exceed 19 degrees Celsius and are doing so more frequently and for longer periods of time. (Nineteen degrees Celsius is considered the upper range of survival for salmonids).<br>Estimate is based on a relatively large level of effort to reduce the threat. It is likely that mitigation will be required in tributaries to implement the action. |
| CRE-3: Protect/enhance instream flows influenced by withdrawals and other water management actions in tributaries. | Estimate is unsupported in the literature.<br>This is a protection action that is intended to reduce the potential for increased threat.<br>Estimate is closely aligned with CRE-4 and probably has overlapping benefits. |

| | |
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| CRE-4: Adjust the timing, magnitude, and frequency of hydrosystem flows. | Estimate is unsupported in the literature.<br>The action affects nearly every facet of estuary ecosystem health.<br>Estimate is intended to demonstrate that changes to the hydrograph are possible and that small increments of change may produce a significant survival improvement.<br>This action is worthy of further analysis that may help support a more defensible survival estimate. |
| CRE-5: Mitigate entrapment of fine sediment in reservoirs. | Estimate is unsupported in the literature.<br>Estimate was assigned a low survival improvement because of the high degree of uncertainty about its potential to improve salmonid survival. Entrapment of sediment may have significantly larger effects. |
| CRE-6: Use dredged materials beneficially. | Estimate is unsupported in the literature.<br>Estimate was assigned a low survival improvement because of the high degree of uncertainty about its potential to improve salmonid survival.<br>Currently, beneficial uses are most often associated with nearshore erosion management, and little is known about potential benefits to salmonids in the nearshore. |
| CRE-7: Reduce entrainment/ habitat effects of dredging and ballast. | Estimate is unsupported in the literature.<br>Estimate is relatively low because of the uncertainty and lack of mortality documentation associated with entrainment. |
| CRE-8: Remove or modify pilings and pile dikes | Estimate is unsupported in the literature.<br>Estimate is relatively high because of the number of pile dikes in the estuary and the suspected predation effects that result from the threat, including predation by cormorants, pikeminnow, bass, walleye, and catfish. Altered flow circulation and reduced juvenile access to low-velocity habitats may also be a threat. |
| CRE-9: Protect/restore high-quality off-channel habitat. | Estimate is unsupported in the literature.<br>This is a protection action that is intended to reduce the potential for increased threat.<br>The high estimate reflects the magnitude of importance that off-channel habitats represent to juveniles, especially ocean types. Because restoration activities are highly constrained, it is vital not to lose additional functioning habitats.<br>Protection alone will only help preserve the status quo. |
| CRE-10: Breach, lower, or relocate dikes and levees. | Estimate is unsupported in the literature.<br>Estimate is intended to demonstrate that dike or levee breaching is one of the top few actions that will increase ocean-type survival in the estuary. If substantial improvements for ocean-type life histories in the estuary are to occur, this is one of a handful of actions that must be implemented.<br>Estimate assumes a significantly higher level of implementation than what is currently occurring. |
| CRE-11: Reduce over-water structures. | Estimate is unsupported in the literature.<br>Estimate is relatively high because of the number of over-water structures in the estuary and the suspected predation effects that result from the threat, including predation by cormorants, pikeminnow, bass, walleye, and catfish.<br>Other effects, such as decreased light penetration, are not well understood. |

| | |
|---|---|
| CRE-12: Reduce vessel wake stranding. | Mortality estimates for test sites have demonstrated a wide range of confirmed mortality. In Bauersfeld (1977), an assessment of five test sites estimated approximately 150,000 stranded juveniles (on those sites). No estuary-wide estimates have been developed.<br>The emerging availability of LIDAR imagery for the estuary may provide for analysis to extrapolate confirmed site-specific information to estuary-wide predictions.<br>Estimate is relatively high within the range of study estimates. |
| CRE-13: Manage pikeminnow and other piscivorous fish. | Estimate is unsupported in the literature.<br>Some information exists about predation rates.<br>The threat does not currently appear to be on the increase.<br>Estimate is relatively high based upon conjecture by the NMFS Northwest Fisheries Science Center regarding pikeminnow predation rates, but the threat should be studied further and monitored over time. |
| CRE-14: Reduce predation by pinnipeds. | An estuary-wide mortality estimate is unsupported in the literature.<br>Estimates are for adults only.<br>Annual counts at Bonneville Dam indicate between 0.4 percent and 3.4 percent mortality of spring Chinook and winter steelhead.<br>A 500-pound Stellar sea lion consumes about 40 to 60 pounds of fish each day.<br>An unsubstantiated estimate of all pinniped predation in the estuary of approximately 10 percent of spring Chinook and winter steelhead is probably reasonable. |
| CRE-15: Reduce invasive plants. | Estimate is unsupported in the literature.<br>Noxious weeds alter food webs and habitat and work at the ecosystem scale.<br>Very little is understood about the connection between noxious weeds and juvenile salmonid survival.<br>Estimate is relatively high for noxious weeds compared to other ecosystem-scale threats because, although associated actions are difficult, they have a greater likelihood of success than do actions to address other similar threats, such as invertebrate infestations. |
| CRE-16: Redistribute Caspian terns. | Estimate is supported by the literature.<br>Recent successes in relocating terns have been documented.<br>Efforts to implement the action are under consideration.<br>Estimated mortality attributed to Caspian tern predation is approximately 3.6 million juveniles in 2005.<br>Current planning calls for a two-thirds reduction in the East Sand Island nesting. |

| | |
|---|---|
| CRE-17: Redistribute cormorants. | Estimate is supported by the literature.<br>Efforts to manage cormorants are not nearly as mature as efforts to manage terns.<br>There is less certainty about implementation potential because cormorants have not responded to management efforts to the degree that terns have.<br>Estimated mortality attributable to predation by double-crested cormorants is considered to be comparable to that of predation by terns.<br>Assignment of the target survival improvement was lower than for terns because cormorants may be harder to manage than terns. |
| CRE-18: Reduce shad abundance. | Estimate is unsupported in literature.<br>Estimate is low because of the high degree of uncertainty about the relationship between shad, salmonids, and ecosystem health.<br>Estimate is also low because the literature does not identify potential actions to reduce shad abundance levels. |
| CRE-19: Prevent aquatic invertebrate introductions. | Estimate is unsupported in the literature.<br>Extent of the threat is well-documented; however, invertebrate infestations occur at the ecosystem scale, and the degree of mortality that occurs because of food web changes at this scale is unknown.<br>Estimate is relatively low because of the uncertainty of the threat and the inherent challenges of reducing the threat. |
| CRE-20: Implement pesticide/fertilizer BMPs. | Emerging literature (Loge et al. 2005) hypothesizes that mortality resulting from estuary contamination ranges from 1.5 percent to 9 percent, depending on the amount of time juveniles spend in the estuary.<br>Estimates for CRE-21, CRE-22, and CRE-23 form the basis for survival improvements (using estimates from Loge et al. 2005). |
| CRE-21: Identify and reduce sources of pollutants. | Emerging literature (Loge et al. 2005) hypothesizes that mortality resulting from estuary contamination ranges from 1.5 percent to 9 percent.<br>Estimates for CRE-20, CRE-22, and CRE-23 form the basis for survival improvements (using estimates from Loge et al. 2005). |
| CRE-22: Restore or mitigate contaminated sites. | Emerging literature (Loge et al. 2005) hypothesizes that mortality resulting from estuary contamination ranges from 1.5 percent to 9 percent.<br>Estimates for actions CRE-20, CRE-21, and CRE-23 form the basis for survival improvements (using estimates from Loge et al. 2005). |
| CRE-23: Implement stormwater BMPs. | Estimate is unsupported in the literature.<br>This is a protection action that is intended to reduce the potential for increased threat.<br>This action does not assume retrofitting of existing stormwater function. |

# Recovery Plan Module
# Mainstem Columbia River Hydropower Projects

## 1.0 Purpose

This module summarizes the general effects of Columbia River mainstem hydropower projects on all 13 Endangered Species Act (ESA)-listed anadromous salmonids in the Columbia basin, including the limiting factors and threats and expected actions (including site-specific management actions), or strategy options, to address those threats. The area to be addressed by the module includes the accessible mainstem habitat in the upper Columbia (i.e., to the tailrace of Chief Joseph Dam) and Snake (i.e., to the tailrace of Hells Canyon Dam) rivers, respectively, downstream to the tailrace of Bonneville Dam.[1] This module supports plans for the Snake River, Upper Columbia, Middle Columbia, Lower Columbia, and Upper Willamette River species, replacing the previous version provided as guidance to regional recovery planners, dated September 25, 2006. The material that follows is a synthesis of information that has undergone public processes for review, including, but not limited to, the Federal Columbia River Power System (FCRPS) 2008 Biological Opinion, Federal Energy Regulatory Commission (FERC) licensing proceedings, and Habitat Conservation Plans (HCPs). This module may, however, be updated as additional information becomes available.

### 1.1 How Salmon and Steelhead Use the Mainstem

All 13 ESA-listed species of salmon *(Oncorhynchus spp.)* and steelhead *(O. mykiss)* in the Columbia basin use the mainstem Columbia River (and Snake River for Snake River species) for migration to and from freshwater natal areas to the Pacific Ocean, where they grow from juveniles to mature adults. Most of the ESA-listed species spawn and incubate in tributaries, but Snake River (SR) fall Chinook, some populations of Lower Columbia River (LCR) fall Chinook, and Columbia River (CR) chum salmon spawn and incubate redds in the mainstem itself. Historically, the peak period for migration to the ocean has been spring and early summer, corresponding with snowmelt in the upper basin and high seasonal flows. However, individual juveniles from one species/population or another can be found in the system throughout the year.

Downstream travel has been shown to be active rather than passive; in addition to water velocity, the rate of travel is affected by date, temperature, the location where the fish begin their migration, fish size, and the extent of the parr-smolt transformation. Survival through the migration corridor declines with distance traveled, whether due to natural hazards (including predation), mortality due to passage at hydroelectric projects, or other factors associated with

[1] A separate module (the Mainstem Columbia River Estuary Recovery Plan Module) provides the same types of information for the lower river below Bonneville, in the estuary and the ocean plume.

development (exotic predators, habitat conditions that make native predators more efficient, water quality, etc.).

Based on emigration and rearing strategies, Connor et al. (2005) described two juvenile life history types for Snake River fall Chinook. At the time of the ESA listing (June 28, 2005; NMFS 2005), it was assumed that all juveniles of this species were ocean-type fish, characterized by entering saltwater at age 0 and spending their first winter in the ocean. However, some of the smaller, later-migrating fall Chinook salmon from the Snake River basin delay seaward movement, wintering in the lower Snake River reservoirs before resuming their seaward movement the following spring at age 1. According to Connor et al. (2005), although the condition of reservoir-type juveniles decreased over winter compared with ocean-type juveniles, the mean condition factor of the former always exceeded 1.0 in the single year of study.

After growth and maturation, whether in freshwater or the ocean, adult salmonids and steelhead generally return to their natal spawning areas for reproduction, though some straying into other basins is natural. As described in ISG (1996), the timing of adult entry and movement in rivers and tributary streams, and even the size, shape, and strength of adult fish represent adaptations to the physical and biological challenges presented by the upstream route to a specific spawning area. For example, waterfalls and similar physical barriers may be passable only at the range of flows that typically occurs during one month of the year, and then only by fish that have the physical ability to jump over or otherwise ascend the barrier. For fall-spawning fish, warm water conditions in late summer often present thermal barriers to movement and there may be little suitable habitat for resting (Berman and Quinn 1991, cited in ISG 1996). Therefore, at the adult life stage, population-specific behavioral patterns, closely attuned to the available habitats, appear to be critical for survival and successful reproduction.

Preferred spawning habitat is determined by the incubation needs of embryos, i.e., high flow of oxygenated water through the interstitial spaces in the streambed (Quinn 2005). Salmon usually avoid both the slowest water (where fine sand and silt accumulate) and the fastest water. Salmon lay their eggs in nests called redds. In areas where winter freezing can destroy embryos, salmon often build redds at sites with upwelling groundwater, which is warmer than river water. In the Columbia basin, two of the listed species, Snake River fall Chinook and Columbia River chum salmon, spawn both in tributaries and in the mainstem. In the vicinity of Ives Island (downstream of Bonneville Dam), chum spawn in shallow areas where it appears that river water is warmed by its transit through the gravel (Geist et al. 2002). At both Ives Island and in the Hanford Reach, fall Chinook salmon select upwelling sites in preference to non-upwelling sites (Geist 2000; Arntzen et al. 2005), but in other locations, fall Chinook prefer to spawn in downwelling areas at the heads of riffles (Healey 1991). At both Ives Island and the Hanford Reach, fall Chinook salmon select redd sites containing the highest dissolved oxygen concentrations in the river and riverbed, which is consistent with the requirements for incubating relatively large eggs (Healy 1991).

## 2.0 Habitat Limiting Factors and Threats Related to Mainstem Hydropower Projects and Operations

This section identifies the past and continuing effects of dams and reservoirs located in the mainstem Columbia and Snake River migratory corridors on listed species of salmon and steelhead and their designated critical habitat. The mainstem migratory corridor extends from the base of Hells Canyon Dam on the Snake River, and from Chief Joseph Dam on the Columbia River, to the tailrace of Bonneville Dam on the Columbia River.

Columbia River Basin anadromous salmon and steelhead have been affected by the development and operation of dams. Mainstem dams have extirpated anadromous fish from their pre-development spawning and rearing habitats. Dams and reservoirs, within the currently accessible migratory corridor, have altered the river environment and have affected fish passage and survival. The operation of water storage projects has altered the natural hydrograph of the Snake and Columbia Rivers. Water impoundment and dam operations also affect downstream water quality characteristics, including water temperatures, which are important to the survival of anadromous fish. Detailed descriptions of these effects are provided in Williams et al. 2005 and Ferguson et al. 2005 (NOAA Technical Memoranda NMFS-NWFSC-63 and 64) and summarized in NMFS 2008a (Supplemental Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of the Upper Snake and other Tributary Actions – Section 5.1).

### 2.1 Blocked and Inundated Habitat

The construction of Grand Coulee Dam in 1939 – River Mile 597 (and later Chief Joseph Dam in 1961 – RM 545) blocked access to important historical production areas for Upper Columbia River (UCR) spring Chinook salmon and steelhead (NRC 1996; ICTRT 2003) upstream of River Mile 597 (and RM 545). In addition to mainstem production areas, the Sanpoil, Spokane, Colville, Kettle, Pend Oreille, and Kootenai rivers each may have supported one or more populations of Chinook and/or steelhead.

In the Snake River, the construction of Swan Falls Dam in 1901 blocked access to important historical production areas of salmon and steelhead in the Snake River basin upstream of RM 424.[2] The construction of the Hells Canyon Dam complex (1958–1967) cut off access to the remaining historical habitat upstream of river RM 248, including seven major tributaries that had historically been important for spring/summer Chinook salmon and steelhead (and to sockeye

[2] The area downstream of RM 578 (near the present location of Upper Salmon Falls Dam) was especially important to Snake River fall Chinook salmon, which Evermann (1896) identified as the "... largest and most important salmon spawning ground of which we know in Snake River."

salmon in the Payette River system): Boise, Burnt, Malheur, Owyhee, Payette, Powder, and Weiser rivers (Fulton 1968; Fulton 1970; Gustafson et al. 1997).

Between 1938 and 1971, the construction of Bonneville, The Dalles, John Day, and McNary dams inundated mainstem habitat in the lower Columbia River between Bonneville Dam (RM 146) and the confluence of the Snake River (RM 324). Between 1933 and 1967, the construction of Priest Rapids, Wanapum, Rock Island, Rocky Reach, and Wells dams inundated mainstem habitat in the middle Columbia River between the Snake River confluence (RM 324) and Chief Joseph Dam (545). Another 147 miles (RM 0 to RM 147) of mainstem habitat was inundated in the Snake River with the construction of Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams between 1962 and 1975 (Groves and Chandler 1999). Upstream from Bonneville Dam, the 41-mile stretch of the Columbia River known as the Hanford Reach between the head of Lake Wallula (McNary Dam pool – RM 356) and the tailrace of Priest Rapids Dam (RM 397), and the approximately 101-mile stretch of the Snake River, often referred to as the Hells Canyon reach (RM 147 to 248), provide the longest remaining unregulated reach of the mainstem ecosystem between Bonneville Dam and Chief Joseph Dam on the Columbia River and Hells Canyon Dam on the Snake River.

### 2.2 Mainstem Habitats & the Migratory Corridor

The Columbia and Snake Rivers (mainstem habitat) serve as corridors for migrating salmon and steelhead between the Pacific Ocean and their freshwater spawning and rearing habitats. Features of migration habitat important to these fish generally include: substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food (prey), riparian vegetation, space, and safe passage. For fall Chinook salmon, and to a lesser extent chum salmon, mainstem habitat also serves as important spawning and rearing habitat. Features of spawning and rearing habitat that are important to these fish generally include: spawning gravel, water quality, water quantity, water temperature, food, riparian vegetation, and access to spawning and rearing areas.

Current conditions within much of the mainstem Columbia and Snake Rivers are altered compared to historical conditions. The development of mainstem hydropower projects have resulted in the inundation of many mainstem spawning and shallow-water rearing areas (loss of spawning gravels and access to spawning and rearing areas); altered water quality (reduced spring turbidity levels), water quantity (seasonal changes in flows and consumptive losses resulting from use of stored water for agricultural, industrial, or municipal purposes), water temperature (including generally warmer minimum winter temperatures and cooler maximum summer temperatures), water velocity (reduced spring flows and increased cross-sectional areas of the river channel), food (alteration of food webs, including the type and availability of prey species), and safe passage (increased mortality rates of migrating juveniles) (Williams et. al 2005; Ferguson et. al 2005).

Within the migratory corridor, both dams and their associated reservoirs influence the current status of Columbia Basin salmon. To a greater or lesser extent specific to each dam, the dams present fish passage hazards, causing passage delays and varying rates of injury and mortality.

#### 2.2.1 Adult Passage

Unlike downstream migrating juveniles, there is no indication that reservoirs substantially delay adult upstream migration (Ferguson et al. 2005). While the upstream migration of adults can be slowed as fish search for fishway entrances and navigate through the fishways themselves, they migrate more quickly through the relatively slow reservoirs.

Adult fish passage, in the form of fish ladders, is provided at the eight mainstem projects in the lower Snake and lower Columbia rivers and the five mainstem FERC-licensed projects in the middle Columbia reach. In general, adult passage facilities are highly effective. Nonetheless, salmon may have difficulty finding ladder entrances, and fish also may fall back over the dam, either voluntarily (e.g., adults that "overshoot" their natal stream and migrate downstream through a dam on their own volition), or involuntarily (entrained in spillway flow after exiting a fish ladder). Some adults that fall back or migrate downstream pass through project turbines and juvenile bypass systems. Adult mortality rates have been estimated at between 22% and 59%, depending on the species and size of the individual fish (larger fish are more likely to contact a turbine blade, etc.) (Ferguson et al. 2005). There is even less data on the survival of adults through juvenile bypass systems. It seems logical to assume that survival rates would be much higher through these systems than through turbine units, and indeed, with the possible exception of passage through the 14 to 16" gatewell orifices, conditions within these systems should be easily navigable by adults.

However, in spite of these potential hazards, average survival estimates using known origin PIT-tagged fish indicate that, after adjusting for known harvest and "natural" straying, survival through the mainstem Snake and Columbia River projects is relatively high (see Table 1 and discussion in Section 4 below).

##### Steelhead Kelts

Unlike other Pacific salmonids, a large fraction of the adult steelhead does not die after spawning and instead attempts to migrate back to the Pacific Ocean. Termed kelts, very few post-spawn adult steelhead survive downstream passage through the hydrosystem and so do not return and spawn again. Estimates of FCRPS passage survival ranged from 4.1 to 6.0% in the low flow year 2001 to 15.6% in 2002 and 34% in 2003 (Boggs and Peery 2004; Wertheimer and Evans 2005). At present, juvenile collection and bypass systems are not designed to safely pass adult fish including kelts. In addition to injury and mortality, kelt downstream migrations are delayed by the mainstem projects (Wertheimer and Evans 2005) in a manner similar to that previously described for juveniles.

The fraction of repeat spawning kelts in steelhead populations varies widely, from 1 to 51% (Wertheimer and Evans 2005). Boggs and Peery (2004) cite an estimated 2% kelt rate for the Clearwater River in 1954. It is estimated that 17 to 25% of the steelhead that pass Lower Granite Dam return downstream as kelts (Boggs and Peery 2004; Wertheimer and Evans 2005). Thus, while there is a relatively large number of kelts present, their relatively poor survival through the FCRPS (and potentially through the Middle Columbia PUD projects) may limit the contribution that they can make to steelhead populations.

#### Predation

Additionally, at Bonneville Dam, marine mammals (both the more common California sea lion and ESA-listed Stellar sea lion) are increasingly using the Bonneville Dam tailrace as a foraging area, presumably because the adult Chinook, steelhead, and lamprey upon which they feed are concentrated and delayed in this area as they seek entrance to the dam's adult fishways.

### 2.2.2 Juvenile Passage

#### Delay

Prior to the development of mainstem dams (c. 1938–1975), the mainstem migratory corridor was free-flowing with high velocities and a broad complex of habitats including rapids, short chutes, falls, riffles, and pools. It is not known how long it took juvenile salmon and steelhead to traverse the free-flowing river. Today, median travel times for yearling Chinook from the Lower Granite Dam on the Snake River to Bonneville Dam range from 14 days to 31 days depending on flow conditions, an increase of 40 to 50% over travel times measured in 1966 (Raymond 1968 and 1979), when fish encountered only the four mainstem dams (Williams et al. 2005).

This increased travel time (migration delay) presents an array of potential survival hazards to migrating juvenile salmon and steelhead: increasing their exposure to potential mortality vectors in the reservoirs (e.g. predation, disease, thermals stress), disrupting arrival timing to the estuary (which likely affects predator/prey relationships),[3] depleting energy reserves, potentially causing metabolic problems associated with smoltification (smoltification is the process of metabolic changes required to allow juvenile fish to convert from freshwater to saltwater environments), and for some steelhead and all Chinook salmon, contributing to residualism (a loss of migratory behavior).

[3] During the spring and summer a series of changes occur in the composition of biotic communities the estuary and near-shore ocean environment. The assemblages of species change through time and disrupting arrival timing may increase the exposure of juvenile salmon to predators and/or diminish the availability of prey species to which the fish are adapted.

Migration delays and biological effects of a similar magnitude have likely also occurred in the middle Columbia River as a result of the construction of the middle Columbia PUD projects.

**Dam Passage**

A substantial proportion of juvenile salmon and steelhead can be killed while migrating through dams, both directly through collisions with structures and abrupt pressure changes during passage through turbines and spillways, and indirectly, through non-fatal injury and disorientation, which leave fish more susceptible to predation and disease and result in delayed mortality. Some juvenile mortality and injury is associated with any route of dam passage, but turbine passage generally has the highest direct mortality rate—8 to 19 percent. Juveniles passing through project spillways, sluiceways and other surface routes generally suffer the lowest direct mortality rates, 2% or less. However, substantially higher mortality rates have been measured through spillways at several mainstem FCRPS projects (Ferguson et al. 2005, NOAA Technical Memoranda NMFS-NWFSC-64).[4]

Additionally, a significant rate of juvenile mortality (approximately 3 to 5%) can occur in project forebays, just upstream of the dams (Axel et al. 2003; Ferguson et al. 2005; Hockersmith 2007), if fish are substantially delayed (median of 15-20 hours) before passing through the dam (Perry et al. 2007).[5] Forebay delay increases the exposure of juveniles to fish and avian predators and increases their exposure time to adverse water quality conditions (e.g. elevated total dissolved gas levels and high water temperatures), where present. (See discussion in NMFS 2008a—Supplemental Comprehensive Analysis, Section 5.1.2.1 for additional information regarding improvements made at the mainstem hydroelectric dams to improve passage since the mid-1990s, including some discussion of how the newly developed surface passage routes are proving effective at reducing forebay delay.)

**Predation**

The altered habitats in project reservoirs reduce smolt migration rates and create more favorable habitat conditions (increased growth rates, increased consumption rates, and enhanced foraging opportunities) for fish predators (see Dam Passage), including northern pikeminnow (*Ptychocheilus oregonensis*), and non-native walleye (*Sander vitreus*) and smallmouth bass (*Micropterus dolomieu*).

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[4] The route-specific mortality rate values given here are averages across several investigations. Higher and lower moralities have been observed and measured route-specific mortality is influenced by an array of factors ranging from the health and species of the test fish to study methods, the performance characteristics and working condition of the system being studied, and environmental conditions.

[5] This study was conducted at McNary Dam; estimates of delay for individual fish ranged from 0 to 172 hours in this study.

Dams also enhance conditions for avian predators - primarily Caspian terns, double-crested cormorants, and several gull species – because these species can more effectively forage in the forebays and tailraces of the mainstem projects than in a more riverine system.

**Transportation Program**

Following a decade of research that led to the conclusion that in most cases, the average adult return rates of predominantly stream-type salmonids (spring/summer Chinook and steelhead) that were transported as juveniles exceeded the return rates of fish that migrated inriver, the Corps began large-scale juvenile transportation as a management measure in 1975 (Ebel 1980; Ebel et al. 1973; Mighetto and Ebel 1994). Currently, fish collection and transportation systems are operated seasonally at Lower Granite Dam, Little Goose Dam, and Lower Monumental Dam (and at McNary Dam for summer migrating fall Chinook salmon). Most transported fish are barged to release points downstream from Bonneville Dam. When collection numbers become too small for barging to be cost-effective, collected fish are transported via truck. Approximately 60 to 90% of spring migrating smolts (spring/summer Chinook and steelhead) in the Snake River basin have been transported annually (Williams et al. 2005). Higher proportions (>95%) of Snake River migrants are likely to be transported during low water year conditions (defined as years in which spring flows are expected to be less than 65,000 cubic feet per second at Lower Granite Dam). With the addition of surface passage routes at the Snake River dams, far fewer fish may be transported – especially early in the migration season when adult returns from Chinook salmon smolts left to migrate inriver are relatively high (compared to transported fish) [see discussion below] – than has been possible in the past. For example, in 2007 transport rates were estimated to be much lower than previously estimated (approximately 25% for wild and hatchery yearling Chinook salmon and about 41% for wild and hatchery steelhead) (Smith 2008).

Recent data show that the effectiveness of transportation, in terms of the ratio of returning adults to transported juveniles (termed smolt-to-adult return ratio or SAR) from the Snake River, varies among species, season, and collection location (Williams et al. 2005; Scheuerell and Zabel 2007). In general, the SARs of both transported and inriver migrating Snake River spring/summer Chinook salmon and steelhead tend to decrease once the day of arrival below Bonneville Dam passes early May. For steelhead, SARs of transported fish are typically equal to or higher than those of the surviving inriver migrants arriving downstream of Bonneville Dam (transport-to-in-river SAR ratios > 1.0). For spring/summer Chinook salmon, SARs of surviving inriver migrating fish often are substantially higher in early to mid May than those of transported migrants (transport-to-in-river SAR ratios < 1.0). However, in late May and June, the differences are generally diminished such that SARs are nearly equal (transport-to-in-river ratios ≈1.0).[6]

[6] The ISAB (2008) recently reviewed this information and generally agreed with NOAA Fisheries' assessment of the currently available data regarding the relative returns of adult Chinook and steelhead that were either transported or left inriver to migrate as juveniles. However, they advised NOAA Fisheries, the federal Action Agencies, and other regional managers to continue a "spread the risk" approach to spill and transport management to determine if

### 2.3 Mainstem Hydrologic Conditions

Flow regulation, water withdrawal, and climate change have reduced the Columbia River's average flow, altered its seasonality, and reduced sediment discharge and turbidity (NRC 1996; Sherwood et al. 1990; Simenstad et al. 1982 and 1990; Weitkamp 1994). Annual spring freshet flows through the Columbia River estuary are about one-half of the pre-development levels that flushed the estuary and carried smolts to sea (Figure 1).

Flow affects juvenile travel time and the distribution of individuals among the various routes of dam passage. In general, the lower the flow through the FCRPS reservoirs, the longer the travel time of juveniles that migrate inriver.[7] The longer juveniles remain in project reservoirs, the greater their exposure to predation, elevated temperatures, disease, and other sources of mortality and injury.

Combined with the influence of reservoirs in the migration corridor, reductions in spring and early summer flows slow juvenile fish emigration, increase their exposure to injury and mortality factors within the reservoirs (e.g. predation, temperature stress, disease, and others), and change the timing of ocean entry.

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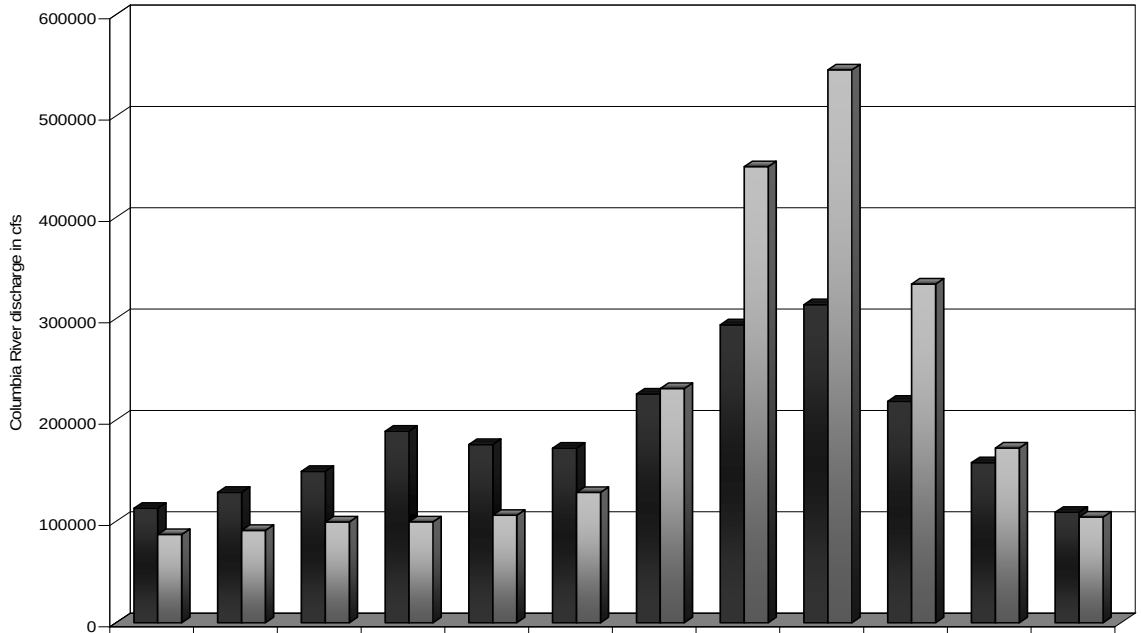
these patterns have been altered by recent structural improvements and operations at the mainstem dams and out of concern for potential effects of spring spill and transport operations [proposed in the 2008 FCRPS biop (NMFS 2008b)] on sockeye and lamprey.

[7] At lower river flows a higher proportion of individuals is collected and transported for some ESUs, thereby avoiding the delay associated with inriver hydrosystem passage.

**Figure 1. Simulated mean monthly Columbia River flows at Bonneville Dam under current conditions (black columns) versus flows that would have occurred without reservoir management (gray) (water years 1929 –1978. Source: Current Condition Flows – Bonneville Power Administration, HYDSIM model run FRIII_07rerun2004biop.xls; Pre-Development Flows – USBR (1999) Cumulative Hydrologic Effects of Water Use: An Estimate of the Hydrologic Impacts of Water Resource Development in the Columbia River Basin. (In NMFS' (2008a) Supplemental Comprehensive Analysis, Section 5.1.3.)**




| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Current | 113017 | 128641 | 149403 | 189076 | 175921 | 172150 | 225689 | 293948 | 313930 | 218523 | 157935 | 109020 |
| Natural | 87115 | 91029 | 99387 | 99496 | 106033 | 128580 | 231047 | 450040 | 545561 | 334238 | 172430 | 104310 |

### 2.4 Mainstem Water Quality

Water quality characteristics of the mainstem Snake and Columbia Rivers are affected by an array of land and water use developments. Water quality characteristics of particular concern are: water temperature, turbidity, total dissolved gas, and chemical pollutants.

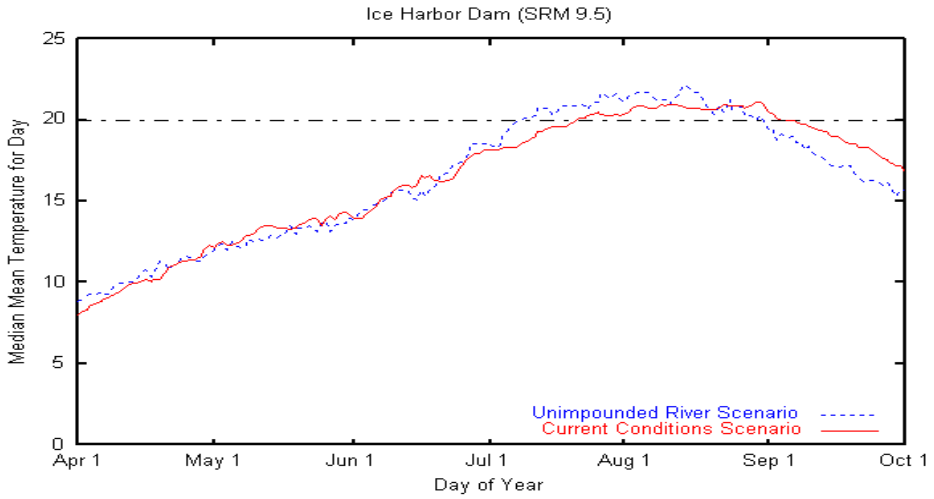
#### *2.4.1 Water Temperature*

Changes in water temperatures can have significant implications for anadromous fish survival. Dams and reservoirs influence water temperatures through storage, diversion, and irrigation return flows. Comparisons of long-term temperature monitoring in the migration corridor before and after impoundment reveal a fundamental change in the thermal regime of the Snake and

Columbia rivers. As shown in Figure 2, there are three notable differences between the current and the unimpounded river:[8]

- the maximum summer water temperature has been slightly reduced,
- water temperature variability has decreased, and
- post-impoundment water temperatures stay cooler longer into the spring and warmer later into the fall. The latter phenomenon is termed thermal inertia.

**Figure 2. Median daily Snake River water temperatures (°C) at Ice Harbor Dam before and after development of the four lower Snake River projects (20°C denotes Washington Department of Ecology standard). Source: Perkins and Richmond 2001 in NMFS 2008a.**




High water temperatures stress all life stages of anadromous fish, increase the risk of disease and mortality, affect toxicological responses to pollutants, and can cause migrating adult salmon to stop or delay their migrations and juvenile steelhead to residualize. Warm water temperatures also increase the foraging rate of predatory fish thereby increasing the consumption of smolts.

Though the duration and magnitude of high water temperatures in the migratory corridor is generally less under current, developed conditions than prior to water development, some juvenile fish are exposed to these conditions for a longer period of time due to the adoption of

[8] NOTE: Significant land use practices, including the development of a large number of water storage and diversion projects had already occurred by the 1960s. Therefore, the unimpounded river scenario in this graphic does not be equate to the pre-development condition.

alternative life histories (i.e, juvenile fall Chinook that over-summer in the mainstem reservoirs) or increases in migration travel time.

Coincident with and possibly due to climate change, average annual Columbia Basin air temperatures have increased by about 1 degree C over the past century and water temperatures in the mainstem Snake and Columbia rivers have been affected similarly (ISAB 2007). The influence of this and other large-scale environmental variations are discussed in NMFS 2008a – Supplemental Comprehensive Analysis, Section 5.7.

Also, due to the thermal inertia of the reservoirs (both mainstem and upstream storage projects), atmospheric cooling of water temperatures is delayed in the fall and warming is delayed in the early spring. This can affect Snake River fall Chinook by increasing the exposure of adults to elevated temperatures prior to spawning, resulting in an increased potential of pre-spawning mortality, reduced gamete viability, and subsequent impacts to the development and survival of fish through the egg to fry life stages.

#### *2.4.2 Turbidity*

Flow regulation and reservoirs reduces turbidity in the Columbia and Snake rivers. Reduced turbidity can increase predator success through improved prey detection, increasing the susceptibility of smolts to predation. Predation is a substantial contributor to juvenile salmon mortality in reservoirs throughout the Columbia and Snake River migratory corridors.

#### *2.4.3 Total Dissolved Gas*

Spill at mainstem dams (either as a means to pass fish or involuntarily in response to over-generational flows) can cause downstream waters to become supersaturated with dissolved atmospheric gasses. Supersaturated total dissolved gas (TDG) conditions can cause gas bubble trauma (GBT) in adult and juvenile salmonids resulting in injury or death. Biological monitoring shows that the incidence of GBT in both migrating smolts and adults remains between 1-2% when TDG concentrations in the upper water column do not exceed 120% of saturation in FCRPS project tailraces and 115% in project forebays. When those levels are exceeded, there is a corresponding increase in the incidence of GBT symptoms.

However, the effects of total dissolved gas (TDG) supersaturation on aquatic organisms are moderated by depth due to hydrostatic pressure. Each meter of depth compensates for about 10% of gas supersaturation as measured at the water surface. Thus, if the dissolved gas concentration is 120% of supersaturation at the surface, then the condition that the aquatic organism actually experiences at a depth of 2.0 meters is reduced to about 100% (i.e., the fishes tissues will be in equilibrium with the surrounding water and it will not develop gas bubble disease or trauma; Weitkamp 2003).

### *2.4.4 Pollutants*

Background or ambient levels of pollutants in inflows from upstream areas are variable and generally unquantified. Growing population centers throughout the Columbia and Snake River basins and numerous smaller communities contribute municipal and industrial waste to the rivers. Mining areas scattered around the basin deliver higher background concentrations of metals. Highly developed agricultural areas of the basin also deliver fertilizer, herbicide, and pesticide residues to the river. While these pollutants are not caused by the mainstem Snake and Columbia rivers projects, they are transported through them to the estuary.

Current environmental conditions in the Columbia River estuary indicate the presence of contaminants in the food chain of juvenile salmonids including DDT, PCBs, and polyaromatic hydrocarbons (PAH) (NMFS 2001). This data also indicates that juvenile salmonids in the Columbia River estuary have contaminant body burdens in the range where sublethal effects can occur. The sources of exposure are not clear, but may be widespread. Several pesticides and heavy metal contaminants have been detected in Columbia River sediments (ODEQ 2007). In field studies, juvenile salmon from sites in the Pacific Northwest have demonstrated immunosuppression, reduced disease resistance, and reduced growth rates associated with contaminant exposure during their period of estuarine residence (Arkoosh et al. 1991, 1994, 1998; Varanasi et al. 1993; Casillas et al. 1995a, 1995b, and 1998). Some impacts may be occurring within the mainstem Columbia and Snake Rivers, to the extent that juvenile fish are rearing in areas that are contaminated to similar levels as in the estuary.

## 3.0 Current Recovery Strategies and Actions

Current hydropower programs and operations are the result of completed or ongoing ESA section 7 consultations, Habitat Conservation Plans (HCPs) pursuant to section 10 of the ESA; FERC relicensing proceedings and other regulatory processes. In most cases, hydropower programs and operations are intended to avoid jeopardy and contribute to recovery. There is no distinction between the hydropower actions intended to meet ESA regulatory requirements and those intended purely for recovery.[9]

[9] Recovery cost estimates do not include costs for implementing mainstem actions, first, because of their basinwide scope and applicability to all 13 Columbia Basin salmonid species listed as threatened or endangered, and second, because they are considered "baseline actions," a term that NMFS' NWR ESA recovery plans use for actions already incorporated into other processes, such as section 7 consultations, FERC licensing agreements, and Habitat Conservation Plans, and these costs would occur regardless of the recovery plans.

### 3.1 Federally Owned and Operated Projects in the Columbia Basin

#### *3.1.1 Federal Columbia River Power System*

The Federal Columbia River Power System (FCRPS) consists of 14 projects, each composed of dams, powerhouses, and reservoirs, that are operated as a coordinated system for power production and flood control (while also effectuating other project purposes) on behalf of the Federal government under various Congressional authorities. These projects are: Dworshak, Lower Granite, Little Goose, Lower Monumental, and Ice Harbor dams, power plants, and reservoirs in the Snake River basin; Albeni Falls, Hungry Horse, Libby, Grand Coulee and Banks Lake (features of the Columbia Basin Project), and Chief Joseph dams, power plants, and reservoirs in the upper Columbia River basin; and McNary, John Day, The Dalles, and Bonneville dams, power plants, and reservoirs in the lower Columbia River basin.

The plan for operation of the FCRPS through 2018 is described in U.S. Army Corps of Engineers (USACE) et al.'s Comprehensive Analysis Document (USACE et al. 2007a) and Biological Assessment (USACE et al. 2007b) and in NMFS' Supplemental Comprehensive Analysis Document (NMFS 2008a) and Biological Opinion (NMFS 2008b). The following is a general summary of the performance standards, metrics, and targets required in the 2008 Biological Opinion to maintain or improve salmon and steelhead survival in the mainstem migration and rearing corridor and the strategies that will be pursued to achieve these metrics (see RPA 51 in NOAA Fisheries' Reasonable and Prudent Alternative Table of Actions – NMFS 2008b). These actions are intended to address the needs for survival and recovery of all 13 species of ESA-listed salmon and steelhead in the Columbia basin.

- **Adult Passage Performance Standards.** The Actions Agencies must track and confirm that the relatively high levels of adult survival currently observed are maintained or increased through 2018 (see Table 7 of NOAA Fisheries' Reasonable and Prudent Alternatives Table of Actions – NMFS 2008b). These survival rates, which are based on known-origin fish PIT tagged as juveniles, after accounting for known harvest and "natural" rates of straying, range from 81.2% for Snake River fall Chinook salmon up to 91.0% for Snake River spring/summer Chinook salmon (BON to LGR); and from 84.5% for Upper Columbia River steelhead up to 90.1% for Upper Columbia River spring Chinook (BON to MCN).[10]
- **Juvenile Dam Passage Performance Standards.** The Action Agencies must achieve an average Juvenile Dam Passage Performance Standards of 96% survival across Snake

[10] The discrepancy between adult survivals for Upper Columbia River versus Snake River species in the lower Columbia River is recognized and is the subject of directed research, monitoring, and evaluation programs. The objectives of these programs are to determine why the differences exist and what actions might be effective at increasing the survival of the Upper Columbia River species in the lower Columbia River.

River and Lower Columbia River dams for spring Chinook and steelhead and an average of 93% survival across Snake River and Lower Columbia River dams for Snake River sub-yearling fall Chinook.

- **Achieve Juvenile Inriver Survival Performance Metrics.** The Action Agencies must annually measure the survival of inriver migrating fish and compare these numbers with COMPASS model estimates, which will be based on the conditions actually experienced and the expected benefits of completed hydro actions, to assure that survival improvements are occurring as expected.
- **Juvenile System Survival Performance Targets.** The Action Agencies must achieve the expected increase in juvenile fish survival through the hydrosystem (survival to below Bonneville Dam of both transported and inriver migrating fish) that are associated with the proposed hydrosystem actions.

To achieve these metrics, the Action Agencies will pursue the following general objectives and strategies (see NOAA Fisheries' Reasonable and Prudent Alternatives Table of Actions, NMFS 2008b, for specific details):

- Continue collaboration with States and Tribes in the implementation of RPA actions, progress reporting, and adaptive management using fora such as the Regional Implementation Oversight Group.
- Operate the FCRPS to provide flows and water quality to improve juvenile and adult fish survival.[11]
- Modify Columbia and Snake river dams to maximize juvenile and adult fish survival.[12]
- Implement spill and juvenile transportation improvements at Columbia and Snake River dams.
- Operate and maintain facilities at Corps mainstem projects to maintain biological performance.
- Implement piscivorous predation control measures to increase survival of juvenile salmonids in the lower Snake and Columbia rivers.

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[11] This includes the operation of storage reservoirs to increase the likelihood of achieving seasonal flow objectives: Spring \ 85 – 100 kcfs at Lower Granite dam, 135 kcfs at Priest Rapids dam, and 220 – 260 kcfs at McNary dam; Summer \ 50-55 kcfs at Lower Granite dam and 200 at McNary. It also includes the continued release of cool water from Dworshak dam during the summer to reduce and maintain temperatures in the lower Snake River.

[12] This includes the design, construction, and testing of structures and operations to provide surface oriented routes of passage which should be beneficial to juvenile migrants and downstream migrating adults (overshoots, fallbacks, or steelhead kelts).

- Implement avian predation control measures to increase survival of juvenile salmonids in the lower Snake and Columbia rivers.
- Implement marine mammal control measures to increase survival of adult salmonids at Bonneville Dam.
- Provide information needed to support planning and adaptive management and demonstrate accountability related to the implementation of FCRPS ESA hydropower actions for all ESUs (i.e., implement research, monitoring, and evaluation programs for hydropower actions and predator control actions).

In addition to these objectives, the 2008 FCRPS Reasonable and Prudent Alternative Action Table articulates site-specific management actions that will benefit interior Columbia species (see NOAA Fisheries' Reasonable and Prudent Alternatives Table of Actions, NMFS 2008b, for specific details).

#### *3.1.2 U.S. Bureau of Reclamation Projects in the Upper Snake Basin above Brownlee Reservoir*

The USBR's proposed actions in its August 2007 Biological Assessment (USBR 2007) addressed operations at 12 projects in the upper Snake River basin: Baker, Boise, Burnt River, Little Wood River, Lucky Peak, Mann Creek, Michaud Flats, Minidoka, Owyhee, Palisades, Ririe, and Vale (collectively, the Upper Snake Project). The proposed actions encompassed USBR's future operations and routine maintenance, including storage and delivery of water, hydropower generation, and releasing water to augment flows for migrating salmonids. NMFS (2008c) prepared a biological opinion on this proposal and concluded that the action would not jeopardize the listed species nor result in the destruction or adverse modification of their designated critical habitat.

The site-specific action of providing salmon flow augmentation is intended to address the needs for survival and recovery of all 13 species of ESA-listed salmon and steelhead in the Columbia basin. Although the physical project operations take place upstream of the migration barrier at Idaho Power Company's Hells Canyon Complex, water released from the upper Snake River project reaches the lower Snake and Columbia rivers where it benefits juvenile salmon and steelhead migrants.

The USBR provides salmon flow augmentation by acquiring water through rental pools and leasing or acquiring natural flow rights. The Nez Perce Water Rights Settlement and the Idaho law that implemented the settlement provide that up to 487,000 acre-feet may be provided for flow augmentation.

### 3.2 Federal Energy Regulatory Commission-licensed Projects

The Federal Energy Regulatory Commission (FERC) licenses five hydroelectric dams in the middle Columbia reach (i.e., between Chief Joseph Dam and the confluence of the Snake and Columbia rivers): Wells (owned and operated by Douglas County Public Utility District (PUD)), Rocky Reach and Rock Island (Chelan County PUD), and Wanapum and Priest Rapids (Grant County PUD). FERC also licenses Idaho Power Company's (IPC) Hells Canyon Complex in the Snake River basin.

#### *3.2.1 Hydropower Projects Owned and Operated by Chelan and Douglas PUDs*

NMFS (2002) entered into three site-specific 50-year anadromous fish agreements and habitat conservation plans (HCPs), one for each of the three mainstem Columbia River hydroelectric projects owned by Chelan (Rocky Reach and Rock Island) and Douglas (Wells) County PUDs, pursuant to section 10 of the Endangered Species Act. The HCPs were developed to protect the five species of Columbia River steelhead and salmon (spring-run Chinook salmon; summer/fall-run Chinook salmon; sockeye salmon, steelhead, and coho salmon, two of which (Upper Columbia River spring-run Chinook salmon and steelhead) were listed as endangered at that time.[13] They satisfied the PUDs' regulatory obligations with respect to anadromous salmonid species under the Federal Power Act, Fish and Wildlife Coordination Act, Pacific Northwest Electric Power Planning and Conservation Act, the essential fish habitat provisions of the Magnuson-Stevens Fishery Conservation and Management Act, and Title 77 RCW, as well as the ESA. The agreements set a "no net impact" standard to protect salmon and steelhead at the Wells, Rocky Reach, and Rock Island projects, and provide some degree of certainty for the long-term operation of these projects.[14]

Each of the three HCPs established a standard of 91% combined adult and juvenile passage survival at each project (Wells, Rocky Reach, and Rock Island) (NMFS 2002).[15] The combined survival standard is composed of 93% juvenile and 98% adult project passage survival for all anadromous salmonids. At the time the Incidental Take Permits were issued (August 20, 2003), NMFS estimated that the HCPs represented a 22 to 45% survival improvement potential over the survival levels observed under the historical operations at these projects.

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[13] NMFS (2006) revised its listing of Upper Columbia River steelhead from "endangered" to "threatened" on January 5, 2006.

[14] The HCPs are intended to help prevent conditions that would lead to the need to list additional species of Upper Columbia River salmon and steelhead in the future.

[15] The HCPs allowed the PUDs to compensate for up to 9% project passage mortality through up to 7% hatchery production and up to 2% funding of tributary habitat enhancement projects. That is, the mitigation is intended to match the level of impact.

### *3.2.2 Hydropower Projects Owned and Operated by Grant County PUD*

Grant County PUD's new FERC license includes survival standards required in NMFS (2004) for the Priest Rapids Project (Priest Rapids and Wanapum dams and reservoirs) that are identical to those described above for the HCPs. Furthermore, the following site-specific measures are also included in the new FERC license and are being implemented to ensure that the standards are met:

- Downstream passage measures, including spill through existing and top spill through future units; turbine operations and the installation of advanced turbines; total dissolved gas abatement; avian predator control; and a northern pikeminnow *(Ptychocheilus oregonensis)* removal program

- Continued operation and maintenance, and where needed, improvements to adult fishways at both Priest Rapids and Wanapum dams

- Design and construction of an off-ladder trap and fish-handling facilities at Priest Rapids Dam

- Sluiceway operations for steelhead fallbacks (kelts)

The FERC has completed consultation with NMFS on the terms of a new, 44-year license for the Priest Rapids Project. With respect to site-specific actions for mainstem facilities and operations, FERC adopted the hydro actions in the Reasonable and Prudent Alternative in NMFS' Biological Opinion on Grant County PUD's Interim Protection Plan (NMFS 2004) and in NMFS' February 1, 2008, Biological Opinion (NMFS 2008d) for listed salmon and steelhead, described above.

### 3.3 Idaho Power Company's Hells Canyon Project

The relicensing of the Hells Canyon Hydroelectric Project is the subject of ongoing administrative proceedings before FERC involving its owner, IPC; Federal, state, and tribal agencies; and other stakeholders. At present, IPC voluntarily operates the project to protect habitat used by fall Chinook salmon for spawning (i.e., by eliminating flow fluctuations), and incubation (i.e., by providing enough flow to prevent the dewatering of redds downstream of the project). As part of an interim settlement agreement in the license proceedings, IPC has agreed to release about 237 thousand acre-feet (kaf) of water – primarily during July - to improve downstream migration conditions (flow) for juvenile fall Chinook salmon (Tucker 2005).

## 4.0 Survival Rates at Mainstem Federal and Non-Federal Hydro Projects

### 4.1 Adult Survival

Adult survival estimates presented in this document are based primarily on a simple, straight-forward "conversion rate" method which relies upon the detection and subsequent re-detection of PIT-tagged "known-origin" adults[16] as they migrate upstream through the fishways (some fitted with PIT tag detectors) at the mainstem hydro projects. Detection rates are typically $\geq$ 99% for an individual PIT tag detector and, because there are typically two or three detectors in series within each of the key fishways –virtually every PIT-tagged adult fish migrating upstream through a mainstem fishways is detected.[17]

Minimum adult survival estimates (or conversion rates) can be calculated as the number of fish re-detected at an upstream project divided by the number of fish initially detected at the downstream project of interest. Estimates of "natural" straying rates and of known harvest are also factored in and the resulting number is the proportion of fish that survived between the two projects. For details regarding this method and how "natural" stray rates and harvest rates were used in these analyses, the reader is advised to read the Adult Survival Estimate Appendix of NOAA's Supplemental Comprehensive Analysis (NMFS 2008a). Otherwise, these estimates capture all sources of mortality manifested within the identified reaches, including those resulting from the existence and operation of the FCRPS, as well as unquantifiable levels of mortality from other potential sources (e.g., unreported or delayed mortality caused by fisheries, marine mammal predator attacks, etc.) and unquantifiable levels of "natural" mortality (i.e., levels of mortality in the migratory corridor that would have occurred "naturally" without human influence).

#### Adult Survival – Federal Projects

Under the 2008 FCRPS Biological Opinion (NMFS 2008b), the federal action agencies are responsible for ensuring that the relatively high rates of survival currently observed in the Bonneville Dam to Lower Granite Dam (7 dams) reach for Snake River species and Bonneville Dam to McNary Dam (3 dam) reach for Upper Columbia River spring Chinook and steelhead is maintained or increased through 2018. Snake River species, for which the most information is available, were used as surrogates for Middle Columbia River steelhead, and Lower Columbia River species. The average survival estimates, annual estimates (ranges), and additional

[16] "Known-origin" means that the release locations for all PIT tagged juvenile fish are available in the PITAGIS data base – and the general area to which these fish are attempting to migrate as adults is also known.
[17] It should be noted that some adults may avoid detection by migrating past the dams via the locks at the federal projects. This is evidenced by individuals not being detected at a particular dam, but being detected at another dam upstream.

information are provided in Table 1 (Column 3 titled "Adult Surv. – FCRPS") and the information for Snake River and Upper Columbia River species is also summarized in the text below.

The average survival estimate for Snake River fall Chinook salmon between Bonneville Dam and Lower Granite Dam was 81% for those that migrated inriver as juveniles and approximately 75% for those that were transported as juveniles, equating to a per project survival (7 dams) of 97% and 96%, respectively.[18]

The average survival estimate for Snake River spring/summer Chinook salmon between Bonneville Dam and Lower Granite Dam was 91% for those that migrated inriver as juveniles and about 84% for those that were transported as juveniles, equating to a per project survival (7 dams) of 99% and 98%, respectively.

The estimated average survival of Snake River sockeye salmon between Bonneville Dam and Lower Granite Dam was 81% equating to a per project survival (7 dams) of about 97%. No estimate can be made with the available data for those fish transported as juveniles (see Table 1, footnote 3).

The average survival estimate for Snake River steelhead between Bonneville Dam and Lower Granite Dam was 90% for those that migrated inriver as juveniles and approximately 83% for those that were transported as juveniles, equating to a per project survival (7 dams) of 99% and 97%, respectively.

The average survival estimate for Upper Columbia River spring Chinook salmon between Bonneville Dam and McNary Dam was 90% (all of these fish migrate inriver as juveniles), equating to a per project survival (3 dams) of approximately 97%.

The average survival estimate for Upper Columbia River steelhead between Bonneville Dam and McNary Dam was 85% (all of these fish migrate inriver as juveniles), equating to a per project survival (3 dams) of 95%.[19]

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[18] Average per project survival estimates are calculated as Average Survival Estimate ^ 1/n. Average per project survival estimates are useful because they allow for a comparison between species that migrate past different numbers of dams.

[19] Note: The apparent discrepancy between the survival rates of Upper Columbia River spring Chinook salmon and steelhead through a 3 dam reach and Snake River spring/summer Chinook salmon and steelhead through a 7 dam reach is noted in the 2008 FCRPS biological opinion. Reasonable and Prudent Alternative Action 52 requires an investigation into the possible causes of this apparent discrepancy (NMFS 2008b). Once a likely cause is identified, the Action Agencies, NOAA Fisheries and co-managing agencies will develop appropriate corrective actions and a monitoring plan to ensure that the differential survival is minimized or eliminated.

**Adult Survival – Non-Federal Projects**

Under the terms of the Middle Columbia Habitat Conservation Plans for the Wells, Rocky Reach, and Rock Island projects; and under the 2008 biological opinion for the Priest Rapids Project (Wanapum and Priest Rapids dams, NMFS 2008d), the Public Utility Districts must meet or exceed a per project survival of 98% for all adult migrants. At this time, it appears that the average per project survival between Priest Rapids and Wells Dam is 98.7% and 98.2% for Upper Columbia River spring Chinook salmon and steelhead, respectively. The average survival estimates, annual estimates (ranges), and additional information for Upper Columbia River species are provided in Table 1 (Column 4 titled "Adult Surv. – Mid-Columbia" and Column 5 titled "Adult Surv. - Total) and also summarized in the text below.

The average survival estimate for Upper Columbia River spring Chinook salmon migrating between Priest Rapids and the Wenatchee, Entiat, and Methow rivers is approximately 95%, 96%, and 97%, respectively. This survival multiplied by the Bonneville to McNary survival estimate[20] yields a Bonneville to Wenatchee, Entiat, and Methow river survival estimate of about 85%, 87%, and 88%.

The average survival estimate for Upper Columbia River steelhead migrating between Priest Rapids and the Wenatchee, Entiat, and Methow rivers is approximately 93%, 95%, and 96%, respectively. This survival multiplied by the Bonneville to McNary survival estimate[19] yields a Bonneville to Wenatchee, Entiat, and Methow river survival estimate of about 79%, 80%, and 82%.

**4.2 Juvenile Survival**

Juvenile survival levels are estimated for two periods (See Tables 2 and 3). The "Current" scenario generally translates to survivals recently observed or estimated (modeled using COMPASS) to have occurred due to operational and configuration changes at the mainstem hydroelectric projects through about 2006. The "Prospective" scenario generally translates to attaining survival levels (if not already attained or exceeded) that are required by the Habitat Conservation Plans for the Wells, Rocky Reach, and Rock Island projects; the 2008 biological opinion for the Priest Rapids project (Wanapum and Priest Rapids Dam) (NMFS 2008d); or modeled using COMASS for the 2008 FCRPS biological opinion (NMFS 2008b). Full attainment of these standards is expected when the FCRPS biological opinion is fully implemented from 2015 to 2018.

[20] A McNary to Priest Rapids (Hanford Reach) survival estimate has not yet been calculated, but is likely less than 100%.

Juvenile survival through the federal projects under both the "Current" and "Prospective" cases was estimated using NOAA Fisheries' COMPASS model. The COMPASS model was populated with the best empirically derived estimates of route-specific passage and survival rates available for juvenile Chinook or steelhead to reflect the "Current" configuration of the hydrosystem. The Federal Action Agencies assessed the likely benefits (specific survival improvements) that should result from additional dam configuration actions required in the 2008 FCRPS biological opinion and these improvements were included in the modeling runs of the "Prospective" scenario. Both the "Current" and "Prospective" configurations and operations were modeled across a 70-year (1928 through 2000) historical water record.

The model provides estimates of survival to below Bonneville Dam for inriver (and transported, if applicable) migrants, proportion of the migrants that would likely be transported (if applicable), and the arrival timing of migrants to the Bonneville dam tailrace for ESA-listed spring and summer Chinook salmon and steelhead from the Snake River, Upper Columbia River, and Middle Columbia River populations.[21] For the purpose of this module, the most relevant pieces of information are likely the survival estimates.

#### *4.2.1 Juvenile Survival – Current*

Estimates of "Current" juvenile survival through the federal projects, ranges of expected survival, and proportion of juveniles expected to be transported are provided in Table 2 (Column 3 - Juv. Survival – FCRPS). These results are broken into two categories (expected average flows at Lower Granite Dam of less than 65 kcfs or greater than >65 kcfs) for Snake River populations to display the likely effect of the "full transport" operation that would occur in the low flow years – which occurs in about 19% (13 of 70) of the years modeled. Estimates of survival for juveniles migrating from the Methow, Entiat and Wenatchee rivers are provided in Column 4 – Juv. Survival – Mid-Columbia; and combined survival estimates are provide in Column 5 – Juv. Survival – Total. A brief summary of this information is provided for spring migrating Snake River and Upper Columbia River Chinook salmon and steelhead populations in the text below.

The average juvenile survival estimate for Snake River spring/summer Chinook salmon is 56% in the LGR > 65 kcfs years and 37% in the LGR < 65 kcfs years. Estimates of the proportion transported are about 64% and 95% in these flow conditions, respectively.

[21] Insufficient data, primarily resulting from the multiple life-history strategies exhibited by Snake River fall Chinook salmon, was available to populate the COMPASS model to estimate juvenile fall Chinook survival through the FCRPS projects. Instead, NOAA Fisheries derived survival estimates from Fish Passage Center data (see NMFS 2008a and 2008b).

The average juvenile survival estimate for Snake River steelhead is 39% in the LGR > 65 kcfs years and 8% in the LGR < 65 kcfs years. Estimates of the proportion transported are about 79% and 94% in these flow conditions, respectively.

The average juvenile survival estimate for Upper Columbia River spring Chinook salmon is 67% through the four FCRPS dams in the lower Columbia River, and 68%, 71%, and 77% for juveniles migrating from the Methow, Entiat, and Wenatchee rivers through the three to five Middle Columbia projects. The total survival estimate for these populations to below Bonneville Dam is 45%, 47%, and 51%, respectively.

The average juvenile survival estimate for Upper Columbia River steelhead is 48% through the four FCRPS dams in the lower Columbia River, and 69%, 72%, and 75% for juveniles migrating from the Methow, Entiat, and Wenatchee rivers through the three to five Middle Columbia projects. The total survival estimate for these populations to below Bonneville Dam is 33%, 34%, and 36%, respectively.

#### *4.2.2 Juvenile Survival – Prospective*

Estimates of "Prospective" juvenile survival through the federal projects, ranges of expected survival, and proportion of juveniles expected to be transported are provided in Table 3 (Column 3 - Juv. Survival – FCRPS). These results are broken into two categories (expected average flows at Lower Granite Dam (LGR) of less than 65 kcfs or greater than >65 kcfs) to display the likely effect of the "full transport" operation that would occur in the low flow years – which occurs in about 19% (13 of 70) of the years modeled. Estimates of survival for juveniles migrating from the Methow, Entiat and Wenatchee rivers are provided in Column 4 – Juv. Survival – Mid-Columbia; and combined survival estimates are provide in Column 5 – Juv. Survival – Total. A brief summary of this information is provided for spring migrating Snake River and Upper Columbia River populations in the text below.

The average juvenile survival estimate for Snake River spring/summer Chinook salmon is 63% in the LGR > 65 kcfs years and 52% in the LGR < 65 kcfs years. Estimates of the proportion transported are about 64% and 95% in these flow conditions, respectively.

The average juvenile survival estimate for Snake River steelhead is 45% in the LGR > 65 kcfs years and 9% in the LGR < 65 kcfs years. Estimates of the proportion transported are about 74% and 89% in these flow conditions, respectively.

The average juvenile survival estimate for Upper Columbia River spring Chinook salmon is 73% through the four FCRPS dams in the lower Columbia River, and 72%, 75%, and 81% for juveniles migrating from the Methow, Entiat, and Wenatchee rivers through the three to five Middle Columbia projects. The total survival estimate for these populations to below Bonneville Dam is 53%, 55%, and 59%, respectively.

The average juvenile survival estimate for Upper Columbia River steelhead is 53% through the four FCRPS dams in the lower Columbia River, and 75%, 78%, and 81% for juveniles migrating from the Methow, Entiat, and Wenatchee rivers through the three to five Middle Columbia projects. The total survival estimate for these populations to below Bonneville Dam is 40%, 41%, and 43%, respectively.

**Table 1: Recent Adult Survival Estimates for ESA-listed Columbia River Basin Salmon and Steelhead Populations Migrating Past Mainstem Hydroelectric Projects Based on PIT-tagged, Known-Origin Adults.[1]**

| **Species** | **Population** | **Adult Surv.[2] – FCRPS** ***Reach*** **Average** Range *Special Info.* | **Adult Surv. – Mid-Columbia[5]** ***Reach*** **Average** Range *Special Info.* | **Adult Surv.[2] – Total** **Average** Range *Special Info.* |
|---|---|---|---|---|
| SR fall Chinook[3] | Single Pop. | ***BON – LGR*** **Inriver: 81.0** (58.8 – 98.6) **Transported: 74.9** (62.4 – 94.7) | | ***BON – LGR*** **Inriver: 81.0** (58.8 – 98.6) **Transported: 74.9** (62.4 – 94.7) |
| SR spr/sum Chinook[3] | All Pops. | ***BON – LGR*** **Inriver: 91.0** 81.6 – 97.9 **Transported: 84.1** *73.7 – 88.0* | | ***BON – LGR*** **Inriver: 91.0** 81.6 – 97.9 **Transported: 84.1** *73.7 – 88.0* |
| SR sockeye[3] | Single Pop. | ***BON – LGR*** **Inriver: 81.1** 79.1 – 83.2 **Transported: (No Est. Available)** | | ***BON – LGR*** **Inriver: 81.1** 79.1 – 83.2 **Transported: (No Est. Available)** |
| SR steelhead[3] | All Pops. | ***BON – LGR*** **Inriver: 90.1** 85.6 – 93.8 **Transported: 83.3** *78.2 – 89.8* (BON – LGR) | | ***BON – LGR*** **Inriver: 90.1** 85.6 – 93.8 **Transported: 83.3** *78.2 – 89.8* (BON – LGR) |

| Species | Population | Adult Surv.[2] – FCRPS *Reach* Average Range *Special Info.* | Adult Surv. – Mid-Columbia[5] *Reach* Average Range *Special Info.* | Adult Surv.[2] – Total Average Range *Special Info.* |
|---|---|---|---|---|
| UCR spring Chinook[6] | Methow | ***BON - MCN*** | ***PRD - WEL*** **94.7** | ***BON – WEL*** **85.3** |
| | Entiat | **Inriver: 90.1** 86.1 – 96.1 | ***PRD - RRE*** **96.2** | ***BON – RRE*** **86.7** |
| | Wenatchee | | ***PRD – RIS*** **97.4** | ***BON – RIS*** **87.8** |
| UCR steelhead[6] | Methow / Okanogan | ***BON - MCN*** | ***PRD - WEL*** **93.0** | ***BON - WEL*** **78.6** |
| | Entiat | **Inriver: 84.5** 77.6 – 90.7 | ***PRD - RRE*** **94.7** | ***BON - RRE*** **80.0** |
| | Wenatchee | | ***PRD – RIS*** **96.4** | ***BON – RIS*** **81.5** |
| MCR steelhead[4,7] | Yakima / Walla Walla | ***BON - (MCN, JDA, and TDA)*** **Inriver: 95.6** 93.5 – 97.3 | | ***BON-(MCN, JDA, and TDA)*** **Inriver: 95.6** 93.5 – 97.3 |
| | Umatilla / John Day | **97.0** 95.6 – 98.2 | | **97.0** 95.6 – 98.2 |
| | Deschutes and BON pool | **98.5** 97.8 - 99.1 | | **98.5** 97.8 - 99.1 |
| LCR Chinook[4] | Spring-run adults | ***BON Pool*** **Inriver: 98.6** 97.1 – 99.7 | | ***BON Pool*** **Inriver: 98.6** 97.1 – 99.7 |
| | Fall-run adults | **96.9** 92.7 – 99.8 | | **96.9** 92.7 – 99.8 |
| LCR steelhead[4,8] | BON pool | ***BON Pool*** **>98.5** >97.8 - >99.1 | | ***BON Pool*** **>98.5** >97.8 - >99.1 |
| CR coho[4] | BON pool | ***BON Pool*** **96.9** 92.7 – 99.8 | | ***BON Pool*** **96.9** 92.7 – 99.8 |
| CR chum[4] | BON pool | ***BON Pool*** **96.9** 92.7 – 99.8 | | ***BON Pool*** **96.9** 92.7 – 99.8 |

Sources: NMFS' 1) Supplemental Comprehensive Analysis Document (May 5, 2008a); and 2) Biological Opinion – Consultation on Remand for Operation of the Federal Columbia River Power System, 11 bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program (May 5, 2008b).

[1] Key to Dams: BON = Bonneville Dam, TDA = The Dalles Dam, JDA = John Day Dam, MCN = McNary Dam, PRD = Priest Rapids Dam, WAN = Wanapum Dam, RIS = Rock Island Dam, RRE = Rocky Reach Dam, WEL = Wells Dam, IHR = Ice Harbor Dam, LMN = Lower Monumental Dam, LGS = Little Goose Dam, and LGR = Lower Granite Dam.

[2] These estimates are based on detections of known origin fish returning to the Columbia River, detected passing Bonneville Dam, and redetected at upstream locations. These estimates have been adjusted to account for estimated harvest and "natural" straying rates of adults within the FCRPS migration corridor, but otherwise capture all other sources of mortality manifested within the identified reaches, including those resulting from the existence and operation of the FCRPS, unquantifiable levels of mortality from other potential sources (e.g., unreported or delayed mortality caused by fisheries, marine mammal predator attacks, etc.), and unquantifiable levels of "natural" mortality (i.e. levels of mortality in the migratory corridor that would have occurred "naturally" without human influence).

[3] Adult survival rates for SR fall Chinook, SR spr/sum Chinook, and SR steelhead are reported separately as either inriver or transported (via barge or truck) to properly reflect their migration history as juveniles. Survival estimates for adult SR sockeye are primarily based on unknown origin (though likely from the Lake Wenatchee or Okanogan River sockeye populations) adults PIT tagged at Bonneville Dam and detected at McNary Dam. The average per dam survival is expanded to a seven dam reach (Bonneville Dam to Lower Granite Dam).

[4] The estimates for these ESUs only apply to those adults migrating to tributaries entering the reservoir upstream of Bonneville Dam, or in the case of MCR steelhead, the adult populations migrating to tributaries entering the Columbia River between Bonneville Dam and McNary Reservoir.

[5] Recent adult survival estimates from Priest Rapids to Wells dam are reported in Anchor Env. and Douglas PUD (2008): 93.0% and 94.7% for summer steelhead (2004-2007) and spring Chinook salmon (2003-2007), respectively. The average per project survival estimates ($1/4^{th}$ root of the reach survival estimate) are 98.2% for steelhead and 98.7% for spring Chinook.

[6] NOTE: A separate estimate for the McNary Dam to Priest Rapids Dam reach has not yet been generated. This will be addressed in the next update of the Recovery Planning Hydro Module.

[7] Within the Bonneville pool, Klickitat River and 15 Mile Creek populations of steelhead are part of the Mid Columbia River steelhead Distinct Population Segment.

[8] Within the Bonneville pool, Hood River and Wind River populations of steelhead are part of the Lower Columbia River steelhead Distinct Population Segment.

**Table 2. "Current" (2002-2009) Juvenile Survival Estimates for ESA-listed Columbia River Basin Salmon and Steelhead Populations Migrating Inriver Past Mainstem Hydroelectric Projects.[1]**

| Species | Population | Juv. Survival - FCRPS *Reach* **Average** (Range) *Special Info.* | Juv. Survival[3] – Mid-Columbia *Reach* **Average (**Range) *Special Info.* | Juv. Survival – Total **Average (**Range) *Special Info.* |
|---|---|---|---|---|
| SR fall Chinook | Single Pop. | ***LGR - BON***<br><br>**18.7 - 55.4**<br>(12.4 – 71.7)<br>*≈ 52% of the juveniles would be transported* | | ***LGR - BON***<br><br>**18.7 - 55.4**<br>(12.4 – 71.7)<br>*≈ 52% of the juveniles would be transported* |
| SR spr/sum Chinook | All Pops. | ***LGR – BON***<br><br>**LGR >65 kcfs**<br>**56.3** (47.5 – 60.8)<br>*≈ 64% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**37.3** (33.8 – 51.3)<br>*≈ 95% of the juveniles would be transported* | | ***LGR – BON***<br><br>**LGR >65 kcfs**<br>**56.3** (47.5 – 60.8)<br>*≈ 64% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**37.3** (33.8 – 51.3)<br>*≈ 95% of the juveniles would be transported* |
| SR sockeye[4] | Single Pop. | ***LGR - BON***<br><br>**LGR >65 kcfs**<br>**36.4** (19.9 – 57.0)<br>*≈ 64% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**8.2** (Unknown)<br>*≈ 95% of the juveniles would be transported* | | ***LGR - BON***<br><br>**LGR >65 kcfs**<br>**36.4** (19.9 – 57.0)<br>*≈ 64% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**8.2** (Unknown)<br>*≈ 95% of the juveniles would be transported* |
| SR steelhead | All Pops. | ***LGR – BON***<br><br>**LGR >65 kcfs**<br>**38.9** (20.3 – 56.9)<br>*≈ 79% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**7.5** (3.3 – 23.1)<br>*≈ 94% of the juveniles would be transported* | | ***LGR – BON***<br><br>**LGR >65 kcfs**<br>**38.9** (20.3 – 56.9)<br>*≈ 79% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**7.5** (3.3 – 23.1)<br>*≈ 94% of the juveniles would be transported* |

| **Species** | **Population** | **Juv. Survival - FCRPS *Reach*** **Average** (Range) *Special Info.* | **Juv. Survival[3] – Mid-Columbia *Reach*** **Average (**Range) *Special Info.* | **Juv. Survival – Total** **Average (**Range) *Special Info.* |
|---|---|---|---|---|
| UCR spring Chinook | Methow<br><br>Entiat<br><br>Wentachee | ***MCN – BON***<br><br>**66.7** (60.9 – 72.9) | ***WEL – PRD***<br>**67.9**<br><br>***RRE – PRD***<br>**70.6**<br><br>***RIS – PRD***<br>**76.7** | ***WEL – BON***<br>**45.3**<br><br>***RRE – BON***<br>**47.1**<br><br>***RIS – BON***<br>**51.2** |
| UCR steelhead | Methow / Okanogan<br><br>Entiat<br><br>Wentachee | ***MCN – BON***<br><br>**47.9** (16.8 – 67.4) | ***WEL – PRD***<br>**68.9**<br><br>***RRE – PRD***<br>**71.7**<br><br>***RIS – PRD***<br>**74.8** | ***WEL – BON***<br>**33.0**<br><br>***RRE – BON***<br>**34.3**<br><br>***RIS – BON***<br>**35.8** |
| MCR steelhead[2,5] | <br><br>Yakima / Walla Walla<br><br>Umatilla / John Day<br><br>Deschutes<br><br>BON pool | ***(MCN, JDA, TDA) – BON***<br><br>**47.6** (17.2 – 67.1)<br><br>**53.6** (23.2 – 72.1)<br><br>**73.0** (61.5 – 77.6)<br><br>**90.0** (80.6 – 93.0) | | ***(MCN, JDA, TDA, BON Pool) – BON***<br><br>**47.6** (17.2 – 67.1)<br><br>**53.6** (23.2 – 72.1)<br><br>**73.0** (61.5 – 77.6)<br><br>**90.0** (80.6 – 93.0) |
| LCR Chinook[2] | BON pool | ***BON Pool***<br><br>**95.1** (94.4 – 95.9) | | ***BON Pool***<br><br>**95.1** (94.4 – 95.9) |
| LCR steelhead[2,6] | BON pool | ***BON Pool***<br><br>**90.6** (80.3 – 94.7) | | ***BON Pool***<br><br>**90.6** (80.3 – 94.7) |
| CR coho[2] | BON pool | ***BON Pool***<br><br>**95.1** (94.4 – 95.9) | | ***BON Pool***<br><br>**95.1** (94.4 – 95.9) |
| CR chum[2] | BON pool | ***BON Pool***<br><br>**95.1** (94.4 – 95.9) | | ***BON Pool***<br><br>**95.1** (94.4 – 95.9) |

Sources: NMFS' 1) Supplemental Comprehensive Analysis Document (May 5, 2008a); and 2) Biological Opinion – Consultation on Remand for Operation of the Federal Columbia River Power System, 11 bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program (May 5, 2008b).

[1] Key to Dams: BON = Bonneville Dam, TDA = The Dalles Dam, JDA = John Day Dam, MCN = McNary Dam, PRD = Priest Rapids Dam, WAN = Wanapum Dam, RIS = Rock Island Dam, RRE = Rocky Reach Dam, WEL = Wells Dam, IHR = Ice Harbor Dam, LMN = Lower Monumental Dam, LGS = Little Goose Dam, and LGR = Lower Granite Dam.

[2] The estimates for these ESUs only apply to those juveniles migrating from tributaries entering the reservoir upstream of Bonneville Dam, or in the case of MCR steelhead, the juvenile populations migrating from tributaries entering the Columbia River between Bonneville Dam and McNary Reservoir.

[3] Current reach survival estimates for the Mid-Columbia projects are based on the following:

- ***Wells (96.2% for spring Chinook and steelhead)*** - average of the 1998 (99.7%) Chinook study, and 1999 (94.3%) and 2000 (94.6%) steelhead studies as reported in NMFS 2002;

- ***Rocky Reach (92.1% for spring Chinook)*** – average of 2004-2005 studies (93.0% and 91.1%, respectively) as reported in Skalski et al (2006), and ***(95.8% for steelhead)*** - average of 2004-2006 studies (98.3%, 93.0%, and 96.0%, respectively) as reported in Anchor Env. and Chelan PUD (2007) and Skalski et al (2006);

- ***Rock Island (93.4% for spring Chinook)*** – average of 2002-2004 studies (95.6%, 93.4%, and 91.4%, respectively) as reported in Anchor Env. and Chelan PUD (2004) and Skalski et al (2006), and ***(94.1% for steelhead)*** – average of 2004-2006 studies (96.6%, 91.6%, and 94.0%, respectively) as reported in Anchor Env. and Chelan PUD (2007) and Skalski et al (2006);

- ***Wanapum and Priest Rapids (82.0% for spring Chinook)*** – estimated using data from PIT tag studies conducted by Chelan PUD in 1998, 2001, 2002, and 2003 as reported in NMFS 2004 – Table A-2 (90.5% per project); and ***(79.5% for steelhead)*** - estimated using data from PIT tag studies conducted by Chelan PUD in 1999 and 2000 as estimated in NMFS 2004 – Table A-2 (89.1% per project).

[4] Williams et al. 2005 provided estimated survival rates ranging for PIT tagged SR sockeye migrating from Lower Granite to McNary Dams in 2000 to 2003. Of these years, 2001, is most representative of the <65 kcfs flow condition – though still conservative because little spill was provided at the mainstem dams for passage in that year. Survival in this year was estimated at 23.9 percent. The remaining years are representative of the >65 kcfs flow condition. Survival rates ranged from 39.7% to 72.5% (average of 56.1%) in these years. An average per project survival was estimated for this reach (LGR to MCN survival ^ (1/4) = 86.5% per project) and then expanded to a Lower Granite to Bonneville Dam (7 project) reach survival estimate (LGR to BON (per project survival estimate ^ 7 = 36.4%).

[5] Within the Bonneville pool, Klickitat River and 15 Mile Creek populations of steelhead are part of the Mid Columbia River steelhead Distinct Population Segment.

[6] Within the Bonneville pool, Hood River and Wind River populations of steelhead are part of the Lower Columbia River steelhead Distinct Population Segment.

**Table 3: "Prospective" (approximately 2014 and beyond) Juvenile Survival Estimates for ESA-listed Columbia River Basin Salmon and Steelhead Populations Migrating Inriver Past Mainstem Hydroelectric Projects.[1]**

| **Species** | **Population** | **Juv. Survival - FCRPS *Reach*** **Average** (Range) *Special Info.* | **Juv. Survival[3] – Mid-Columbia *Reach*** **Average (**Range) *Special Info.* | **Juv. Survival – Total** **Average (**Range) *Special Info.* |
|---|---|---|---|---|
| SR fall Chinook | Single Pop. | ***LGR - BON***<br><br>**18.7 - 55.4**<br>(12.4 – 71.7)<br>*≈ 52% of the juveniles would be transported* | | ***LGR - BON***<br><br>**18.7 - 55.4**<br>(12.4 – 71.7)<br>*≈ 52% of the juveniles would be transported* |
| SR spr/sum Chinook | All Pops. | ***LGR – BON***<br><br>**LGR >65 kcfs**<br>**62.8** (58.0 – 67.8)<br>*≈ 64% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**51.9** (46.7 – 57.2)<br>*≈ 95% of the juveniles would be transported* | | ***LGR – BON***<br><br>**LGR >65 kcfs**<br>**62.8** (58.0 – 67.8)<br>*≈ 64% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**51.9** (46.7 – 57.2)<br>*≈ 95% of the juveniles would be transported* |
| SR sockeye[4] | Single Pop. | ***LGR - BON***<br><br>**LGR >65 kcfs**<br>**42.8** (23.5 – 64.6)<br>*≈ 64% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**9.8** (Unknown)<br>*≈ 88% of the juveniles would be transported* | | ***LGR - BON***<br><br>**LGR >65 kcfs**<br>**42.8** (23.5 – 64.6)<br>*≈ 64% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**9.8** (Unknown)<br>*≈ 88% of the juveniles would be transported* |
| SR steelhead | All Pops. | ***LGR – BON***<br><br>**LGR >65 kcfs**<br>**45.3** (23.9 – 64.5)<br>*≈ 74% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**9.1** (4.0 – 20.7)<br>*≈ 89% of the juveniles would be transported* | | ***LGR – BON***<br><br>**LGR >65 kcfs**<br>**45.3** (23.9 – 64.5)<br>*≈ 74% of the juveniles would be transported*<br><br>**LGR <65 kcfs**<br>**9.1** (4.0 – 20.7)<br>*≈ 89% of the juveniles would be transported* |

| **Species** | **Population** | **Juv. Survival - FCRPS *Reach*** **Average** (Range) *Special Info.* | **Juv. Survival[3] – Mid-Columbia *Reach*** **Average (**Range) *Special Info.* | **Juv. Survival – Total** **Average (**Range) *Special Info.* |
|---|---|---|---|---|
| UCR spring Chinook | Methow<br><br>Entiat<br><br>Wentachee | ***MCN – BON***<br><br>**72.6** (65.4 – 79.6) | ***WEL – PRD***<br>**72.3**<br><br>***RRE – PRD***<br>**75.1**<br><br>***RIS – PRD***<br>**80.8** | ***WEL – BON***<br>**52.5**<br><br>***RRE – BON***<br>**54.5**<br><br>***RIS – BON***<br>**58.7** |
| UCR steelhead | Methow / Okanogan<br><br>Entiat<br><br>Wenatchee | ***MCN – BON***<br><br>**52.8** (17.3 – 73.8) | ***WEL – PRD***<br>**75.0**<br><br>***RRE – PRD***<br>**78.0**<br><br>***RIS – PRD***<br>**81.4** | ***WEL – BON***<br>**39.6**<br><br>***RRE – BON***<br>**41.2**<br><br>***RIS – BON***<br>**43.0** |
| MCR steelhead[2,5] | Yakima / Walla Walla<br><br>Umatilla / John Day<br><br>Deschutes<br><br>BON pool | ***(MCN, JDA, TDA) – BON***<br><br>**52.4** (17.9 – 73.3)<br><br>**57.9** (23.9 – 77.7)<br><br>**76.8** (64.5 – 82.2)<br><br>**90.3** (80.3 – 93.2) | | ***(MCN, JDA, TDA, BON Pool) – BON***<br><br>**52.4** (17.9 – 73.3)<br><br>**57.9** (23.9 – 77.7)<br><br>**76.8** (64.5 – 82.2)<br><br>**90.3** (80.3 – 93.2) |
| LCR Chinook[2] | BON pool | ***BON Pool***<br><br>**95.5** (94.6 – 96.2) | | ***BON Pool***<br><br>**95.5** (94.6 – 96.2) |
| LCR steelhead[2,6] | BON pool | ***BON Pool***<br><br>**90.8** (79.9 – 94.8) | | ***BON Pool***<br><br>**90.8** (79.9 – 94.8) |
| CR coho[2] | BON pool | ***BON Pool***<br><br>**95.5** (94.6 – 96.2) | | ***BON Pool***<br><br>**95.5** (94.6 – 96.2) |
| CR chum[2] | BON pool | ***BON Pool***<br><br>**95.5** (94.6 – 96.2) | | ***BON Pool***<br><br>**95.5** (94.6 – 96.2) |

Sources: NMFS' 1) Supplemental Comprehensive Analysis Document (May 5, 2008a); and 2) Biological Opinion – Consultation on Remand for Operation of the Federal Columbia River Power System, 11 bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(1)(A) Permit for Juvenile Fish Transportation Program (May 5, 2008b).

[1] Key to Dams: BON = Bonneville Dam, TDA = The Dalles Dam, JDA = John Day Dam, MCN = McNary Dam, PRD = Priest Rapids Dam, WAN = Wanapum Dam, RIS = Rock Island Dam, RRE = Rocky Reach Dam, WEL = Wells Dam, IHR = Ice Harbor Dam, LMN = Lower Monumental Dam, LGS = Little Goose Dam, and LGR = Lower Granite Dam.

[2] The estimates for these ESUs only apply to those juveniles migrating from tributaries entering the reservoir upstream of Bonneville Dam, or in the case of MCR steelhead, the juvenile populations migrating from tributaries entering the Columbia River between Bonneville Dam and McNary Reservoir.

[3] Prospective reach survival estimates for the Mid-Columbia projects are based on the following:

- ***Wells (96.2% for spring Chinook and steelhead)*** - average of the 1998 (99.7%) Chinook study, and 1999 (94.3%) and 2000 (94.6%) steelhead studies as reported in NMFS 2002;

- ***Rocky Reach (93.0% for spring Chinook)*** – assumes that the minimum survival requirement of the Rocky Reach Habitat Conservation Plan will be met (NMFS 2002), and ***(95.8% for steelhead)*** - average of 2004-2006 studies (98.3%, 93.0%, and 96.0%, respectively) as reported in Anchor Env. and Chelan PUD (2007) and Skalski et al (2006);

- ***Rock Island (93.4% for spring Chinook)*** – average of 2002-2004 studies (95.6%, 93.4%, and 91.4%, respectively) as reported in Anchor Env. and Chelan PUD (2004) and Skalski et al (2006), and ***(94.1% for steelhead)*** – average of 2004-2006 studies (96.6%, 91.6%, and 94.0%, respectively) as reported in Anchor Env. and Chelan PUD (2007) and Skalski et al (2006);

- ***Wanapum and Priest Rapids (86.5% for spring Chinook and steelhead)*** – assumes the minimum survival standard (93.0% per project) for these species will be achieved (NOAA 2004).

[4] Williams et al. 2005 provided estimated survival rates ranging for PIT tagged SR sockeye migrating from Lower Granite to McNary Dams in 2000 to 2003. Of these years, 2001, is most representative of the <65 kcfs flow condition – though still conservative because little spill was provided at the mainstem dams for passage in that year. Survival in this year was estimated at 23.9 percent. The remaining years are representative of the >65 kcfs flow condition. Survival rates ranged from 39.7% to 72.5% (average of 56.1%) in these years. An average per project survival was estimated for this reach (LGR to MCN survival ^ (1/4) = 86.5% per project) and then expanded to a Lower Granite to Bonneville Dam (7 project) reach survival estimate (LGR to BON (per project survival estimate ^ 7 = 36.4%). To estimate the expected increase in survival between the "current" and "prospective" conditions, these estimates were adjusted by the estimated survival improvement of SR steelhead in the >65 kcfs flow year condition (45.3% [Prospective] - 38.9% [Current] = 6.4%) resulting in an estimate of 42.8% (36.4% + 6.4%). This was also done for the <65 kcfs flow year condition (9.1% [Prospective] – 7.5% [Current] = 1.6%) resulting in an estimate of 9.8% (8.2% + 1.6%).

[5] Within the Bonneville pool, Klickitat River and 15 Mile Creek populations of steelhead are part of the Mid Columbia River steelhead Distinct Population Segment.

[6] Within the Bonneville pool, Hood River and Wind River populations of steelhead are part of the Lower Columbia River steelhead Distinct Population Segment.

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*Appendix F*

# Ecological Interactions White Paper

# Cumulative Impact of Hatchery Origin Fish on Natural Origin Fish in the Columbia River Estuary

**The Importance of the Columbia River (CR) Estuary**

There is a strong consensus that estuaries are important in terms of providing rearing habitat for growth, potential refuge from predation and a physiological transition before emigrating to the higher salinity in the marine environment (Quinn 2005, Thorpe 1994). Unfortunately, the Columbia River (CR) estuary has suffered a major loss of shallow water rearing habitat in the past century. This loss of habitat has been documented by Bottom et al. 2005 in their excellent treatment of the role of the CR estuary in the Decline and Recovery of Pacific Salmon in which they point out that the loss of wetland habitat since 1870 has been a major factor in the capacity of the estuary to support juvenile salmon. It is estimated that 77% of tidal marshes and 62% of swamps which existed before 1870 have been lost. The diking and filling of marshes and swamps have reduced the surface area by 20% (Bottom et al. 2005). These changes in the CR estuary in terms of habitat loss are likely to have the biggest impact on the capacity to support juvenile salmon: however, the impact of habitat loss in the CR estuary in terms of salmonid carrying capacity is unknown (Bottom et al 2005). More specifically, it has been established that subyearling Chinook and chum are species that use the CR estuary more than other species. Chinook are found in the estuary in every month of the year but were most abundant from May to September whereas chum fry are found in the estuary from March to June (Bottom et al. 1983, Dawley et al. 1986, McCabe et al. 1986). These two species, subyearling Chinook and chum salmon, show a preference for shallow water marsh and swamp habitat.

In Rich's pioneering work of Chinook life history patterns in the CR estuary, he determined from Chinook scales that 5 forms of Chinook life history types were common prior to 1920 (Rich 1920). These life history strategies are characterized by fall Chinook that are subyearlings and which emigrate to the estuary and to the ocean in their first year of life. Bottom et al 2005 has concluded that the Chinook life history diversity described by Rich 1920 has been simplified by habitat loss and has concentrated the remaining salmon into more limited and fragmented regions. The spring Chinook, steelhead and coho life history forms are characterized as stream type and emigrate to the estuary after one year in freshwater. These larger smolts were primarily found to be migrating in the thalweg of the CR in the deepwater channels, side channels and to a lesser extent in shallow water areas as contrasted with the subyearling ocean type habitat distribution behavior (Dawley 1986 et al., Schreck et al. 1995-1997, Schreck and Stahl 1998).

This use of the shallow water habitat in the estuary by fall Chinook is described by field studies in other Northwest estuaries and can be extrapolated to the CR. However, lack of research in the CR estuary in the tidal channel, sloughs, and marshes habitats presently limit the understanding of rearing requirements of CR fall Chinook salmon (Bottom et al. 2005). It is important to understand that the CR estuary has suffered anthropogenic impacts to the present day that are inhibiting the possibility that the historical life history patterns are able to evolve and thrive.

Given the impact of habitat loss in the estuary, the cumulative impact of hatchery origin fish (HOF) on natural origin fish (NOF) in the estuary is a significant scientific research

uncertainty. The HSRG 2009, Bottom et al. 2005, Fresh et al. 2005, Naish 2008 and Kostow 2009 support this point.

The effect of (HOF) on listed (NOF) is a significant and important issue to the CR Basin. The effects of ecological interactions (competition, predation and disease transfer) of HOF on listed NOF represents a tradeoff of risks weighed against the economic benefits of harvesting hatchery fish. Research studies on ecological interactions have been conducted in freshwater but there is a paucity of information in the mainstem, estuary, and near shore marine environment in terms of the cumulative impact of large numbers of hatchery releases. This is relevant at the present time because of the concerns over the risks of using hatcheries to address the decline of listed stocks of salmon and steelhead in the Columbia River (Mitchell Act DEIS 2010).

Recently, the Columbia River Hatchery Reform System-Wide Report by the Hatchery Scientific Review Group 2009, the Review of Hatchery Science by the Recovery Implementation Science Team (RIST) 2009 and the Recommendations for Broad Scale Monitoring to Evaluate the Effects of Hatchery Supplementation on the Fitness of Natural Salmon by the Ad Hoc Supplementation Monitoring and Evaluation Workgroup 2008 have reviewed the genetic risks of hatcheries but did not address the risks from ecological interactions. This is because of large data gaps in research in the mainstem, estuary and the near-shore marine environments as contrasted to the number of studies in the freshwater environment.

It is an important perspective to understand that salmon and steelhead in a natural setting have evolved to avoid competing between species as this is a waste of energy resources. Natural selection pressures on these salmon populations have promoted a fascinating array of micro habitat partitioning and temporal differences to avoid competition for limiting resources of food and space (Quinn 2007, Naish et al. 2008). In other words, unique life history strategies have evolved to maximize food and spatial resources in order to maximize marine survival. Previous research in the Columbia River estuary by (Rich 1910) as reported in Bottom et al. 2005 has documented the rich variability found for Chinook salmon juveniles in terms of utilization of the estuary habitat. Seasonal seine hauls and trawl surveys have documented partitioning of the estuary habitat by salmon and steelhead both spatially and temporally. The use of the estuary varies by species, age and season. For example, chum salmon juveniles have evolved to utilize the estuary shallow water habitats of the estuary as they leave the freshwater streams. Chum salmon emigrate from the freshwater streams soon after emergence from the gravel and are essentially fry when they enter the estuary. As such they are potentially vulnerable to predation so they have evolved an earlier timing into the estuary during February through April. In the pristine state spatial and temporal overlap of species would be minimized in the estuary as mechanisms to avoid competition for food and space would have evolved. The contemporary landscape for the CR estuary is a sharp contrast to the pristine situation in terms of habitat simplicity and ecological impact (Bottom et al. 2005).

While information on the distribution of hatchery and natural origin smolts in the estuary is limited it can be summarized as large stream type yearling spring Chinook and steelhead and coho smolts are found in the main, deep water channels of the estuary while underyearling ocean type Chinook and chum are found in the shallow tidewater margins (Dawley et al. 1986, Bottom et al. 2005, McCabe 1986).

**Competition**

The general principle of competition is that it is the demand by two or more individuals of the same or different species for a resource that is actually or potentially limiting Larkin (1956).

Fresh (1997) points out that competition is a natural process in shaping the abundance of salmon and steelhead throughout their evolutionary history. Fresh (1997) goes on to state that these anadromous salmonids have evolved characteristics that minimize loss of fitness due to the effects of competition otherwise they would have been extinct. In the case of the CR estuary where wild salmon and hatchery salmon co-exist for a time, they may compete directly for limited resources of food and space through agonistic interactions as in interference competition, or by exploitative competition through depletion of food (Berejekian et al 2009).

The cumulative impact of multiple HOF on NOF is an uncertainty at the present time because ecological interactions are least studied in estuaries as compared to freshwater environments, and most studies have evaluated only the impact on single hatchery programs or single watersheds in freshwater (Pearsons 2008). Pearsons (2008) makes the point that exploitative competition may be important in estuary environments that experience large numbers of hatchery fish at different times. Supporting his point, Fresh (1997) states that competition generally is most likely to occur between hatchery and wild salmonids in the estuarine environments where food resources are limited and fish become concentrated on their way to the ocean. With respect to the CR estuary, Fresh (1997) states that to his knowledge estimates of the amount of food available does not exist even though studies cite dietary overlap as evidence of interspecific competition and because of that are not conclusive if food is not limiting. Moreover, because so little is known about salmonid behavior and ecology in the CR estuary between HOF and NOF salmon it is difficult to conclude that actual competition for limited resources is occurring (Flagg et al. 2000).

Based upon the knowledge gained from studies in freshwater it is documented that intraspecific competition is greater in magnitude than interspecific competition due to greater niche overlap within species than between. (Fraser 1969, Allee 1974, Bisson et al.1988, Lonzarich 1994, Flagg et al 2000, Hasegawa and Maekawa 2008). Fresh 1997 points out that interspecific competition is one mechanism used to partition scarce resources like habitat and food in streams (Hartman 1965, Glova 1986, Fausch and White 1986, Hearn 1987). Further, competition among sympatric (co-occuring) salmonid species is minimized by species specific differences in habitat preference (Hearn 1987, Bisson et al 1988, Dolloff and Reeves 1990.

An interesting study by Leven and Williams 2002 has found a negative effect of Snake River hatchery steelhead releases on wild Snake River Chinook salmon. In their paper the authors speculate that stress is a possible mechanism based upon the hatchery steelhead size dominance over wild Chinook when confined to barges which transport these two species below Bonneville dam. The stress was described in laboratory studies reported by Maule et al. 1996 and could make these Snake River wild spring-summer Chinook vulnerable to predation after release from the barges (Leven and Williams 2002). This is a possible working hypothesis that could be tested by further research and as Berejekian et al. 2009 suggest that updating this study with data collected since the original publication could improve the precision of the relationship and offer new insights.

As a conclusion to their recent review Berejekian et al. 2009 states that ecological interactions are regulated by habitat partitioning among species and species-specific estuary resident times. This is especially germane to the present discussion of the cumulative impact of hatchery origin salmon on natural origin salmon in the CR estuary.

Research which is summarized here has shown that stream type salmon, steelhead yearlings, yearling spring Chinook and yearling coho salmon smolts being larger and having greater swimming speed migrate as smolts in the deeper water main channel habitats and they past thorough the CR estuary more quickly than ocean type salmon, subyearling fall Chinook and chum salmon, which spend time rearing and tend to occupy shallow water habitats like peripheral bays, marshes and swamps.

**Predation**

Salmon and steelhead reside in estuaries and nearshore environments before moving in to off shore marine habitats (Healey 1980, Simenstad et al. 1982, McCabe et al 1986, Pearcy 1992). Among salmonid species estuarine residency can vary from days to months within different estuaries and between years based upon environmental conditions of temperature, stream flow, prey availability, and the physical characteristics of estuaries (HSRG 2004, Simenstad et al 1982). As contrasted with studies in freshwater there is little evidence that wild salmonids are preyed on by other salmonids in estuarine or nearshore environments (HSRG 2004). Intrageneric predation in the CR estuary was rare according to McCabe 1986. Generally, cutthroat trout and steelhead smolts were thought to be primary fish predators in estuaries (Emmett 1997, Simenstad et al. 1992, Fresh NOAA Fisheries NW Fisheries Science Center 2009, personal communication). Coho salmon smolts in the CR estuary were found with stomach contents almost entirely comprised of invertebrates and no salmonids as prey (Durkin 1982). Fresh (1997) indicates that much of the information on predation of hatchery fish on wild salmonids is circumstantial, for example, from analysis of fishery management databases. Fresh (1997) uses the example of the dramatic decline of Puget Sound chum salmon runs associated with coho salmon hatchery program initiation (Johnson 1973). In his analysis, Johnson concluded that hatchery coho were the cause of the sharp decline in wild chum salmon populations but it is possible that other factors such as degraded spawning habitat were responsible (Johnson 1973). Berejekian et al. (2009) pointed out literature that supports the predation saturation theory that predation may decrease in the prey population if the numbers of hatchery produced fish exceeds the capacity of predator population to consume additional prey (Peterman and Gatto 1978, Ruggerone and Rodgers 1984, Fresh and Schroder (1987).

On the other hand, increases in predator populations based upon long term hatchery production in the CR have resulted in an increase in Northern pike minnow populations and of avian predators such as Caspian terns (Kim et al 1986, Beamsderfer and Reiman 1991). The implication of these findings is that wild fish are potentially at risk in the CR estuary due to non salmonid and avian predators as well which are attracted to abundant hatchery fish.

The HSRG (2004) has concluded that within the estuarine environment that intrageneric predation of wild juvenile salmonids is not common but they acknowledge that this may reflect difficulties in sampling but also the limited number of studies compared to the freshwater environment. Moreover, they suggest that the relative risk of predation by hatchery fish may be low compared to more significant predation by marine fish.

Additionally, they state that they are unaware of research studies that have been designed to look for predation by hatchery reared salmonids in estuarine or nearshore habitats (HSRG 2004). Very recent research being conducted by NOAA Fisheries NW Fisheries Science Center in the CR estuary with regard to food habitats of HOF yearling Chinook and steelhead juveniles indicates that these species have either empty stomachs or if full have non-salmonid fish, insects or amphipods but not juvenile salmonids (Laurie Weitkamp, NOAA Fisheries NW Fisheries Science Center. 2009, personal communication).

**Disease Transfer**

A recent review by Naish et al 2008 concludes that there is little known about the risk of disease transfer from hatchery fish to wild fish. The concern is that hatchery fish could potentially amplify and transmit endemic disease pathogens to susceptible wild fish. At this time, this is a gap in knowledge and is an uncertain risk with regard to the CR estuary specifically. Other informative publications include an extensive review in Flagg et al 2000, Kostow 2009 and RIST 2009.

**Analysis of the numbers of salmon smolts reaching the CR estuary**

Based upon the previous discussion of research implications of the cumulative effect of HOF and NOF in the CR estuary it is illustrative to look at the relative proportion of HOF to NOF by ESU and species for all smolts entering the CR estuary (Table 1). This data has been summarized from the 2007 smolt emigration year and is an estimate of the number of smolts entering the CR estuary after river mortality has been taken into account. The data for HOF are actual release numbers from the 2007 release year. In contrast, the NOF numbers are estimates of the natural production of smolts derived from the AHA model which is habitat based and calculates the smolt production from population productivity and habitat capacity. As such, the numbers of NOF are derived from the model so the estimates may not accurately reflect the actual numbers of smolts emigrating from freshwater streams and entering the estuary in any given year.

**Table 1 - Number of NOF and HOF Smolts Entering the Columbia River Estuary in 2007**

| ESU | Smolt Type | |
|---|---|---|
| | Natural | Hatchery |
| Columbia River Chum | 4,957,380 | 299,923 |
| Deschutes River Summer/Fall-run Chinook | 588,375 | - 0 |
| Lower Columbia River Chinook | 3,980,763 | 51,094,476 |
| Lower Columbia River Coho | 566,517 | 16,472,024 |
| Lower Columbia River Steelhead | 189,064 | 2,920,754 |
| Middle Columbia River Spring-run Chinook | 198,466 | 3,391,020 |
| Middle Columbia River Steelhead | 282,457 | 466,625 |
| Snake River Basin Steelhead | 371,216 | 4,510,839 |
| Snake River Fall-run Chinook | 95,179 | 1,566,741 |
| Snake River Sockeye | 2,163 | 51,581 |
| Snake River Spring/Summer-run Chinook | 395,252 | 4,241,739 |
| Southwest Washington Steelhead | 32,733 | 321,635 |

| | | |
|---|---|---|
| Upper Columbia Coho | 195,541 | 2,967,394 |
| Upper Columbia River Spring-run Chinook | 120,309 | 1,690,940 |
| Upper Columbia River Steelhead | 111,382 | 405,533 |
| Upper Columbia River Summer/Fall-run Chinook | 4,953,016 | 11,459,932 |
| Upper Willamette River Chinook | 274,650 | 5,574,448 |
| Upper Willamette River Steelhead | 177,737 | 594,356 |
| Wenatchee River Sockeye | 328,990 | 86,801 |

Table 2 displays the number, percentage and species composition of HOF and NOF smolts that reach the CR estuary. The information in Table 2 estimates that 86% of the smolts reaching the estuary are of HOF versus 14% NOF. This data clearly shows that HOF are the majority of salmon smolts reaching the CR estuary under all alternatives.

**Table 2 - Species Composition of HOF and NOF Smolts Reaching the Columbia River Estuary in 2007**

| | **Species Composition** | |
|---|---|---|
| | % | **Totals** |
| **HOF TOTALS** | 86 | 108,116,762 |
| **NOF TOTALS** | 14 | 17,821,190 |
| **TOTALS** | | 125,937,952 |
| **HOF** | | |
| Fall Chinook | 52 | 56,263,555 |
| Spring Chinook | 20 | 21,582,092 |
| Coho | 18 | 19,439,418 |
| Steelhead | 9 | 9,219,742 |
| Chum | 1 | 299,923 |
| **NOF** | | |
| Fall Chinook | 47 | 8,317,018 |
| Spring Chinook | 13 | 2,288,989 |
| Coho | 4 | 762,058 |
| Steelhead | 7 | 1,164,589 |
| Chum | 28 | 4,957,380 |

The data from Table 2 suggest that 52% of the HOF are Fall Chinook at roughly 56 million smolts as contrasted to the NOF model estimate which are 47% Fall Chinook at just over 8 million smolts. The estimated proportion of NOF, which are chum salmon fry is 28% or 4.9 million. Chum salmon smolt production in the CR estuary is estimated to be larger for NOF than HOF. The fact that fall Chinook HOF and chum NOF are so abundant represents a significant challenge as they reach the CR estuary because based upon the previous discussion of research findings the habitat these species are dependent on is the most impacted.

**Table 3 - Intraspecific and Interspecific Interactions of HOF and NOF Smolts Reaching the Columbia River Estuary in 2007**

| Interaction Type | Density Metric |
|---|---|
| Hatchery Fall Chinook X Natural Fall Chinook | 6.8 |
| Hatchery Spring Chinook X Natural Fall Chinook | 2.6 |
| Hatchery Fall Chinook X Natural Chum | 11.3 |
| Hatchery Spring Chinook X Natural Chum | 4.4 |
| Hatchery Coho X Natural Fall Chinook | 2.3 |
| Hatchery Coho X Natural Chum | 3.9 |
| Hatchery Steelhead X Natural Fall Chinook | 1.1 |
| Hatchery Steelhead X Natural Chum | 1.9 |
| Hatchery Steelhead X Natural Steelhead | 7.9 |
| Hatchery Coho X Natural Coho | 25.5 |
| Hatchery Steelhead X Natural Spring Chinook | 4.0 |
| Hatchery Spring Chinook X Natural Spring Chinook | 9.4 |

Table 3 displays the density ratio or metric for intraspecific and interspecific ecological interactions by species. This metric measures the number of HOF smolts to model estimates of the number of NOF smolts that reach the estuary. Calculating the density metric is a measure of quantifying the potential risk of competition and/or predation that might occur in the estuary. The nature of this impact (competition, predation and to a lesser extent disease transfer) is dependent on the species evaluated. For example, the ecological interaction literature discussed earlier suggests that intraspecific interactions are expected to produce higher risk of negative impacts from the point of view of competition for food or space in the estuary. Data from Table 3 indicates that 4 of the 5 highest densities are from intraspecific interactions of HOF on NOF from coho which is the highest (25.5) to Fall Chinook as the lowest (6.8). The exception to this is the interspecific interaction of HOF Spring Chinook on NOF chum which is high (11.3) and could be an indicator of the risk of predation since HOF spring chinook will be over 50% larger than NOF chum salmon in the estuary. If we interpret Table 3 from the point of view of competition risk we would focus on the intraspecific interactions of HOF on NOF. To reiterate, the highest densities were found for HOF coho on NOF coho. The literature from freshwater streams suggests HOF coho have significant advantages in competitive interactions over NOF coho such that NOF can be displaced from territories in streams. These impacts could translate to the CR estuary and underscore a cause for concern (Berejekian et al 1999, Flagg et al 1995, Nielson 1994, Nickelson 2003, Rhodes and Quinn 1999). The second highest densities for intraspecific interactions were for HOF Spring Chinook on NOF Spring Chinook (9.4). There is an indication in the literature of a negative relationship between Snake River HOF spring Chinook and NOF spring Chinook during poor climate years compared to

average years suggesting when food is perhaps limited that competition is greater (Leven et al 2001). This research does not propose a causal mechanism but it does represent an elevated risk in terms of intraspecific interaction. In a similar manner, HOF steelhead on NOF steelhead (7.9) shows the third highest densities of all the species interactions. Kostow and Zhou 2006 and Kostow 2009 indicate the negative ecological impact of Clackamas, Oregon HOF steelhead on NOF steelhead as contrasted with Levin and Williams 2002 work which showed no relationship between Snake River HOF steelhead and NOF steelhead independent of climate conditions. The specific habitat and temporal overlap of these HOF and NOF is unknown and represents a data gap. Spring Chinook, coho and steelhead are all stream type fish and as the literature discussed earlier suggests they tend to migrate through the estuary more quickly than ocean type species and if the hatchery fish are true smolts, they should show a tendency to migrate out of the estuary. Very current data on food habitats of steelhead and yearling spring Chinook show no evidence of salmonid prey being eaten (Laurie Weitkamp, NOAA Fisheries, Northwest Fisheries Science Center. 2009, personal communication). On the other hand, densities of HOF fall Chinook on NOF fall Chinook are high (6.8) and can suggest an impact in terms of competition for food and space. This species exhibits an ocean type evolutionary strategy and research has shown that it has the longest estuarine residency of any species in the CR. As such, there is the real potential for the risk of ecological interaction in terms of competition; however, little data is available to confirm or deny. The other source of concern is the serious loss of shallow water habitat in the CR estuary and the fact that rearing habitat will be in short supply. The highest of the interspecific interactions is for HOF fall Chinook on NOF chum(11.3) which has the potential for competition and/or predation. Both of these species use the estuary extensively and potentially have similar shallow water habitat requirements. As such the higher density value represents a higher risk from the impact of ecological interactions. This data together with the spatial and temporal overlap of salmon smolts in the CR estuary is a method to evaluate risk and can be an approach to explore risk reducing strategies. A practical application of this approach would involve focusing on the highest densities and developing a hatchery release guideline to lower smolt numbers and spread out release times over the season in an effort to lower densities relative to NOF of the same species. Present hatchery release timing guidelines are a mixture of past experiments on size and time of release which were aimed at optimizing marine survival, physiological readiness to osmoregulate and avoidance of predation risk on NOF smolts but a strategy of sequencing the releases based upon near-shore prey abundance should be considered as optimizing early marine survival while ameliorating impacts of high densities of HOF to NOF in the estuary.

**Conclusions**

1. The significant habitat loss of shallow water habitat in the CR estuary has narrowed the fully functioning life history options of the historical subyearling fall Chinook phenotypes as well as chum salmon fry which depend on the estuary for rearing.
2. There is a pressing need for habitat restoration initiatives in the CR estuary. This is particularly critical since the most abundant HOF smolts being produced and the most abundant NOF smolts are subyearling fall Chinook.
3. Hatcheries are producing large numbers of yearling smolts with stream type life history strategies that tend to migrate quickly and occupy the deep water channels in the estuary.
4. HOF fall Chinook subyearlings probably rear in the estuary and could overlap

spatially and temporally with NOF fall Chinook and NOF chum and as such represent a higher risk for ecological interactions.

5. The risk of HOF coho as predators on chum fry could be higher if HOF coho are released from hatcheries too early so that they overlap temporally.
6. Intraspecific competition between HOF fall Chinook and NOF Fall Chinook can be a potential risk from the point of view of competition for food. This competition could compromise growth in NOF Fall Chinook such that it would take longer to reach a critical size threshold above which mortality from predation will be reduced.
7. Less available shallow water estuarine habitat will impact NOF ocean type species such as fall Chinook and chum and could increase density and therefore competition with HOF fall Chinook.
8. Conduct field research on the temporal and spatial habitat needs and food preferences of HOF and NOF species in the CR estuary.
9. Investigate the level of predation of HOF and NOF yearling stream type species such as, steelhead, spring Chinook, coho and cutthroat through studies of food habitats and habitat distribution.

**Recommendations**

1. Work with agencies and tribes to incorporate a system wide approach as is suggested by HSRG 2009 in their recommendation 11 generally, and more specifically, seek to minimize any negative ecological interactions associated with the cumulative impact of HOF on NOF in the CR estuary. HSRG recommends limiting the hatchery production to the minimum needed to meet the system wide harvest and conservation goals of the various managers taking into account the carrying capacity of the mainstem, estuary and ocean.
2. Implement HSRG 2009 recommendation 13 working with agencies and tribes to maximize survival of HOF consistent with conservation goals. Methods discussed essentially involve releasing quality smolts that are actively smolting so they will more rapidly emigrate from the CR estuary.
3. Evaluate innovative methods to spread out HOF releases so as to reduce densities of HOF to NOF in the CR estuary and time the releases so HOF potential predators enter the CR estuary after chum fry reach a critical minimum size.
4. Identify research priorities to address data gaps in knowledge for temporal and spatial habitats requirement of HOF and NOF in the CR estuary.
5. Implement the principle outlined in HSRG 2009 that states monitor, evaluate and adaptively manage hatchery program to become more effective in meeting goals for conservation and harvest. The application of this principle should be applied to critical research in the CR estuary that will define how to avoid the risk of negative cumulative impacts of HOF on NOF.
6. Conduct studies to evaluate the fate of released HOF and NOF smolts after release from smolt transportation barges below Bonneville Dam.
7. Conduct modeling exercises working with agencies and tribes to evaluate methods of spreading out the releases from hatcheries so as to reduce the high densities of HOF fall Chinook as they reach the CR estuary. This approach will allow the exploration of concepts to reduce the temporal overlap and thereby lower the risk of ecological interactions of HOF fall Chinook on NOF fall Chinook and chum salmon.

8. Conduct a series of one day expert panel workshops to identify critical research gaps in knowledge of freshwater, main stem, estuary and near shore marine habitats on ecological interactions that would provide additional guidance on development of recommendations for development of research designs.
9. Recommend modeling approaches where feasible to further quantify risk in freshwater, estuary and near-shore marine habitats both in terms of single hatchery impacts on single natural listed stocks, as well as, cumulative effects of hatchery stocks on natural listed stocks.

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*Appendix G*

# Habitat Concerns Data Dictionary

# Appendix G
# Habitat Concerns Data Dictionary

This appendix presents a standardized list of habitat-related concerns that affect salmon and steelhead in the Pacific Northwest. The NMFS Northwest Fisheries Science Center developed this so-called "data dictionary" (Hamm 2012) to facilitate the use of a common parlance in discussing limiting factors in Northwest Region salmon and steelhead recovery plans. For the Lower Columbia River ESU recovery plan, NMFS Northwest Region staff expanded the initial, habitat-oriented data dictionary in this appendix to include hydropower, harvest, and hatchery concerns; the result served as a framework for summarizing stratum- and ESU-level limiting factors and threats. (See Appendix H for a fuller description of how NMFS correlated limiting factor information from the Oregon, Washington, and White Salmon management unit plans with the ecological concerns terminology of the NMFS data dictionary.)

Two versions of the habitat concerns data dictionary are included in this appendix: a full version complete with definitions of habitat concerns and subcategories, and an abbreviated version that excludes definitions.

| Limiting Factors | ID | Habitat Concern | Definition | Alternate Terms | ID | Habitat Concern-Sub Category | Definition | Alternate Terms |
|---|---|---|---|---|---|---|---|---|
| Habitat-Spawning and egg incubation, Habitat-Rearing, Habitat-Adult | 1 | Habitat Quantity | Insufficient quantity of total habitat or habitat diversity due to the elimination of access | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers | Loss of access to habitat and/or habitat sub-types due to anthropogenic activity. Includes partial or ephemeral barriers. | Access, Barriers, Access to Side-Channels, Flap Gates, Tidal Gates, Culverts, Obstacles, Obstructions, Passage Issues, Blocked |
| | | | | | 1.2 | Natural Barriers | Lasting natural barriers to stream or estuary access, including waterfalls, sand bars, log jams, sufficiently steep gradients or insufficient water. May represent the end of good quality habitat | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient |
| Direct Mortality | 2 | Direct Mortality | Induced instantaneous mortality. | Predation, Disease, Species Interactions | 2.1 | Predation | Introduced salmon predators or changes to the habitat that increase native predator numbers or increase predator success. | Invasive/Exotic Fish or Invertebrate Predators Native Fish, Native Bird, Native Pinnipeds |
| | | | | | 2.2 | Pathogens | Introduction of disease causing organisms or parasites. | Disease, Sea Lice, |
| Direct Mortality | 3 | Toxic Contaminants | Exposure to chemical substances capable of causing sub-lethal or lethal impacts to individuals or offspring. | Pollution | 3.1 | Water | Direct exposure to toxic substance in the water column. | Short-term Toxicity, Stormwater Discharge, Outfalls, Wastewater, Non-point Source Pollution, Spills, Marine Debris, Point Source Pollution, Copper, Mercury |
| | | | | | 3.2 | Biota | Toxics substances found in prey that negatively affect salmon. Includes persistent toxic substances that are concentrated as they are consumed and move to the next trophic level . | Bioaccumulation Toxicity, PBDEs, PCBs, Oil, Organochlorides , Pesticides |
| Food | 4 | Food | Insufficient food for salmonids. | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Alteration of ecological dynamics affecting the quantity, quality and/or species composition of phytoplankton or detritus resulting in insufficient food available for salmonids or prey species. | Micro and Macro-Detrital Inputs, Loss of Marine Derived Nutrients, Carcasses, Down-welling, Ocean Conditions, Detritus, Phytoplankton |
| | | | | | 4.2 | Competition | Insufficient food due interspecific and intraspecific (hatchery produced) competition. | Hatchery Fish, Increased Natural Competitors, Invasive Species |
| | | | | | 4.3 | Altered Prey Species Composition and Diversity | Alteration of ecological dynamics affecting the species composition, distribution or nutritional quality of zooplankton, macroinvertebrates, forage-fish or other prey resulting in insufficient food for salmonids. | Species Diversity, Prey Species Abundance, Invasive Species, Altered Food Web Dynamics |
| Habitat-Spawning and egg incubation, Habitat-Rearing, Habitat-Adult | 5 | Riparian Condition | Degradation of the habitat adjacent to streams, rivers, lakes and nearshore environments. Impairment of the near-bank environment to support plants including large trees that help stabilize stream banks, provide shade, add primary production to the aquatic ecosystem and includes the supply of mature trees into streams as LWD. | Impaired Riparian Function/Condition, microclimate, lack of shade | 5.1 | Riparian Condition | Disturbance to streamside ecological relationships, including but not limited to, loss of flora, erosion and increased light and temperatures | Bank Degradation, Cover, Canopy, Inability to supply organic matter and filter sediments, Insufficient buffers, Light, Loss of Natural Shade |
| | | | | | 5.2 | LWD Recruitment | Loss of mature streamside trees that may become instream structures and associated decline in habitat complexity | LWD supply |
| Habitat-Rearing, Habitat-Adult | 6 | Peripheral and Transitional Habitats | Loss and degradation of relatively flat peripheral habitat of streams and rivers that is periodically inundated during high flows. Includes associated sloughs, side-channels, and freshwater wetlands important for rearing. Includes factors that contribute to multiple limiting factors | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Loss and degradation of side-channels, associated sloughs and freshwater wetlands important for rearing. Includes loss of connectivity | Side Channels, Sloughs, Wetlands, Peripheral Habitat, swamp |
| | | | | | 6.2 | Floodplain Condition | Loss and degradation of relatively flat peripheral habitat of streams and rivers that is periodically inundated during high flows. Includes loss of connectivity due to anthropogenic alterations | Floodplain, Bank Condition, Overbank Area |
| | | | | | 6.3 | Esturary Conditions | Loss and degradation of saltwater transition zone | Estuary, Salt-water Transistion Zone, Lagoon, Estuary Plume, Delta, Slough |
| | | | | | 6.4 | Nearshore Conditions | Loss and degradation of shallow water nearshore habitat | Beaches, tidal flats, eelgrass beds, kelp forest, baitfish spawning grounds |
| Habitat-Spawning and egg incubation, Habitat-Rearing, Habitat-Adult | 7 | Channel Structure and Form | Changes to River, Stream, Lake. Estuarine tributary and Distributary channel form, causing bedload movement including the loss (scour) or fill (aggradation) of the channel and associated loss of spawning habitat, disruption to passage and loss of instream ecosystem function | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Changes to River, Stream, Lake. Estuarine tributary and Distributary channel form, causing bedload movement including the loss (scour) or fill (aggradation) of the channel and associated loss of spawning habitat, disruption to passage and loss of instream ecosystem function | Connectivity, Levees, Dikes, Loss of sinuosity, Isolated Floodplain, Loss of Peripheral Habitat, Bank Hardening, Channel Incision, Channelized, Aggradation, Bed substrate stability, Armoring, Bridge Crossings, Diking, Confinement, Nearshore sediment loss, Beach erosion |
| | | | | | 7.2 | Instream Structural Complexity | Decline of the instream habitat quality. Based on the degree of habitat complexity and variety, includes the quantity and variability of stream depth and pools of varying size and depth. | LWD, Pools, Boulders, Bank Overhang, Cover, Refuge, Habitat Structure, Instream Habitat, Habitat, Stream Complexity, High Quality Over-Winter Rearing Habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat, Channel Conditions, Instream Roughness, Poor Gravel/Sediment Sorting |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Habitat-Spawning and egg incubation, Habitat-Rearing, Physiological Thresholds | 8 | Sediment Conditions | Reduction of the quantity or quality of spawning habitat due to changes to the background (natural) quantity, rate, and size of sediment inputs to the stream system. | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Decreased Sediment Quantity | Decreased input of sediment to the stream system. | Sediment Quantity, Substrate Quantity, Scour, Entrenchment, Loss of Spawning Habitat, Lack of spawning Gravel |
| | | | | | 8.2 | Increased Sediment Quantity | Increases input of sediment to the stream system. | Bank Erosion, Sediment Quantity, Substrate Quantity, Excessive Sedimentation, Aggradation, Sediment Load, Excess Fines, Embededness, Sediment Size Ratio |
| Habitat-Spawning and egg incubation, Habitat-Rearing, Habitat-Adult, Physiological Thresholds, Direct Mortality | 9 | Water Quality | Degraded chemical, physical, and biological characteristics of water with respect to its suitability for a salmon, excluding toxins and pathogens. | | 9.1 | Temperature | Water temperature deviations, either in intensity or duration, sufficient to have adverse effects on listed salmonids | Winter Cover Inadequate, Low Winter Water Temperatures |
| | | | | | 9.2 | Oxygen | Oxygen concentration deviations sufficient to induce adverse effects in listed salmonids. | Eutrophication, Excess Nutrients |
| | | | | | 9.3 | Turbidity | Increased concentrations of suspended fine particulate matter sufficient to have adverse effects in listed salmonids, including reduction of their foraging ability and/or degradation of ecosystem function. | Suspended sediments, Plume Effects, |
| | | | | | 9.4 | pH | Acidity/alkalinity deviations sufficient to adversely effect salmonids or the species on which they feed. | Alkalinity, Ocean Acidification, CO2 |
| | | | | | 9.5 | Salinity | Salinity at concentrations harmful to salmon | Refuge from Salinity Regimes |
| Habitat-Spawning and egg incubation, Habitat-Rearing, Habitat-Adult, Physiological Thresholds, Direct Mortality | 10 | Water Quantity | Detrimental effects of deviations to the background (natural) amount and timing of water quantity instream, including lowered water quality and barriers to access. | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Increased Water Quantity | Habitat disturbance associated with abnormally (compared to background) high water flow and increased "flashiness", including loss of channel substrate and the flushing of young fish downstream. | High Flow, High Volume, Flooding, Plume Changes, Increased Velocity, Increased Peak Flows, Decreased Flood Lag Time, Redd Scouring, Flashiness, Increased Runoff, Water Storage Capability, Road Density |
| | | | | | 10.2 | Decreased Water Quantity | Habitat disturbances associated with abnormally (compared to background) low water flow, including but not limited to, increased temperature, loss of sediment, nutrients and barriers to passage and redd dewatering. | Low Volume, Low Flows, Redd Dewatering, Water Withdrawals, Surface Impoundments, Diversions, Lake Level, Plume Changes |
| | | | | | 10.3 | Altered Flow Timing | Habitat changes associated with alterations to the background (natural) timing of water quantity instream. | Water Releases, Impervious Surfaces, Urbanization, Low Flows, Dewatering |

| ID | Habitat Concern | Alternate Terms | ID | Habitat Concern Sub-Category | Alternate Terms |
|---|---|---|---|---|---|
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers | Access, Barriers, Access to Side-Channels, Flap Gates, Tidal Gates, Culverts, Obstacles, Obstructions, Passage Issues, Blocked |
| | | | 1.2 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Predation | Invasive/Exotic Fish or Invertebrate Predators<br>Native Fish, Native Bird, Native Pinnipeds |
| | | | 2.2 | Pathogens | Disease, Sea Lice |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Short-term Toxicity, Stormwater Discharge, Outfalls, Wastewater, Non-point Source Pollution, Spills, Marine Debris, Point Source Pollution, Copper, Mercury |
| | | | 3.2 | Biota | Bioaccumulation Toxicity, PBDEs, PCBs, Oil, Organochlorides, Pesticides |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Micro and Macro-Detrital Inputs, Loss of Marine Derived Nutrients, Carcasses, Down-welling, Ocean Conditions, Detritus, Phytoplankton |
| | | | 4.2 | Competition | Hatchery Fish, Increased Natural Competitors, Invasive Species |
| | | | 4.3 | Altered Prey Composition and Diversity | Species Diversity, Prey Species Abundance, Invasive Species, Altered Food Web Dynamics |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, microclimate, lack of shade | 5.1 | Riparian Condition | Bank Degradation, Cover, Canopy, Inability to supply organic matter and filter sediments, Insufficient buffers, Light, Loss of Natural Shade |
| | | | 5.2 | LWD Recruitment | LWD supply |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Side Channels, Sloughs, Wetlands, Peripheral Habitat, swamp |
| | | | 6.2 | Floodplain Condition | Floodplain, Bank Condition, Overbank Area |
| | | | 6.3 | Estuary Conditions | Estuary, Salt-water Transition Zone, Lagoon, Estuary Plume, Delta, Slough |
| | | | 6.4 | Nearshore Conditions | Beaches, Tidal Flats, Eelgrass Beds, Kelp Forest, Baitfish Spawning Grounds, Nearshore sediment loss, Beach erosion |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Connectivity, Levees, Dikes, Loss of sinuosity, Isolated Floodplain, Loss of Peripheral Habitat, Bank Hardening, Channel Incision, Channelized, Aggradation, Bed substrate stability, Armoring, Bridge Crossings, Diking, Confinement |
| | | | 7.2 | Instream Structural Complexity | LWD, Pools, Boulders, Bank Overhang, Cover, Refuge, Habitat Structure, Instream Habitat, Habitat, Stream Complexity, High Quality Over-Winter Rearing Habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat, Channel Conditions, Instream Roughness, Poor Gravel/Sediment Sorting |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Decreased Sediment Quantity | Sediment Quantity, Substrate Quantity, Scour, Entrenchment, Loss of Spawning Habitat, Lack of spawning Gravel |
| | | | 8.2 | Increased Sediment Quantity | Bank Erosion, Sediment Quantity, Substrate Quantity, Excessive Sedimentation, Aggradation, Sediment Load, Excess Fines, Embededness, Sediment Size Ratio |
| 9 | Water Quality | | 9.1 | Temperature | Winter Cover Inadequate, Low Winter Water Temperatures |
| | | | 9.2 | Oxygen | Eutrophication, Excess Nutrients |
| | | | 9.3 | Turbidity | Suspended Sediments, Plume Effects |
| | | | 9.4 | pH | Alkalinity, Ocean Acidification, CO2 |
| | | | 9.5 | Salinity | Refuge from Salinity Regimes, Freshwater Outflow |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Increased Water Quantity | High Flow, High Volume, Flooding, Plume Changes, Increased Velocity, Increased Peak Flows, Decreased Flood Lag Time, Redd Scouring, Flashiness, Increased Runoff, Water Storage Capability, Road Density |
| | | | 10.2 | Decreased Water Quantity | Low Volume, Low Flows, Redd Dewatering, Water Withdrawals, Surface Impoundments, Diversions, Lake Level, Plume Changes |
| | | | 10.3 | Altered Flow Timing | Water Releases, Impervious Surfaces, Urbanization, Low Flows, Dewatering |

*Appendix H*

# Limiting Factors Crosswalk and Methodology

# Appendix H
# Limiting Factors Crosswalk and Methodology

## Background and Purpose

To facilitate the use of a common parlance in discussing limiting factors in all Northwest Region salmon and steelhead recovery plans, the NMFS Northwest Fisheries Science Center developed a standardized set of limiting factors (also known as ecological concerns) that affect salmon and steelhead (Hamm 2012; see Appendix G).[1] NMFS refers to this standardized list of limiting factors as a "data dictionary" and intends to use it to track and report on recovery plan limiting factors and actions regionwide.

For the Lower Columbia River ESU recovery plan, NMFS Northwest Region staff developed a set of limiting factor "crosswalk" tables that correlate population-specific limiting factor information from the Oregon, Washington, and White Salmon management unit plans (ODFW 2010, LCFRB 2010a, and NMFS 2011b) with the terms in the data dictionary. The crosswalk tables indicate the limiting factors that affect each population, as well as the life stage affected, the degree and location of the impact, and, in certain cases, uncertainty regarding data and whether limiting factors have been accurately identified. The crosswalk tables served as the basis for the summaries of stratum- and ESU-level limiting factors and threats in Chapters 6 through 9 of the Lower Columbia River ESU recovery plan.

This appendix presents the crosswalk tables and describes the methods NMFS Northwest Region staff used to develop them.

## Crosswalk Methodology

**Step 1:** *Developed "crosswalks" that correlated the limiting factor terms used in each management unit plan with the ecological concerns terminology of the NMFS data dictionary (Hamm 2012; see Appendix G) and made minor adjustments to the data dictionary as indicated below.*

To accomplish this, NMFS Northwest Region staff correlated limiting factor codes used in the management unit plans with ecological concern subcategories in NMFS' initial data dictionary (which was limited to habitat-related concerns) by keying the data dictionary's lists of "alternate terms" to terms used in the management unit plans. The Oregon management unit plan's limiting factor terms (see Table 5-1 of ODFW 2010) correlated relatively directly with the habitat data dictionary's alternate terms, although in some cases NMFS Northwest regional office staff added subcategories to the data dictionary to better reflect the level of specificity in the Oregon plan. (This was the case mainly for estuary limiting factors). The limiting factors described in the Washington management unit plan also crosswalked readily with the data dictionary's ecological

[1] For the purpose of the crosswalk tables, the terms "limiting factor" and "ecological concern" are interchangeable. The latter is perhaps a more appropriate term, but the former has become widely accepted through common usage and is employed throughout the Lower Columbia River ESU recovery plan.

concerns but were sometimes broader than the ecological concerns listed in the data dictionary (see Table 1 in Appendix E of LCFRB 2010a). Many of the terms used to describe limiting factors in the White Salmon management unit plan are the same as those in the Washington management unit plan (see Tables 5-2 and 5-3 in NMFS 2011b). The only adjustment needed in the crosswalks to accommodate the White Salmon populations was the addition of an ecological concern subcategory that specifically addresses excessive sediment issues associated with removal of Condit Dam.

**Step 2:** *Developed color codes to denote a limiting factor's priority and the life stage affected.*

| | Adult | uvenile | A& |
|---|---|---|---|
| Primary | **X** | **X** | **X** |
| Secondary | X | X | X |

**Step 3:** *Completed crosswalk tables to display limiting factors for each population and applied color coding as indicated in Step 2.*

The Oregon management unit plan identified all limiting factors as either primary or secondary, so these categorizations were transferred directly from the Oregon management unit plan (ODFW 2010).

For Washington populations, NMFS Northwest Region staff worked with LCFRB staff and consultants to determine whether a particular habitat limiting factor should be designated as primary or secondary in the crosswalk. Washington habitat limiting factor information was drawn from the Washington management unit plan's Ecosystem Diagnosis and Treatment (EDT) habitat factor analysis tables (see individual chapters of LCFRB 2010a, Volume II), which identified limiting factors as primary, secondary, or tertiary, and also from the impact percentages in the baseline impact tables in Chapter 6 of LCFRB 2010a, which identified population-level impacts for tributary and estuary habitat. In the crosswalk tables, baseline impacts of between 10 and 35 percent are classified as secondary, and any impact greater than 35 percent is classified as primary. Some professional judgment was required to populate the crosswalk tables for Washington populations. In addition, in some cases, LCFRB staff and consultants considered the EDT results highly uncertain. Limiting factors where this is the case are indicated in the crosswalk tables with a question mark, rather than an "X."

For estuary limiting factors, NMFS Northwest Region staff assumed that all populations are subject to the same threats. Furthermore, because the Oregon management unit plan had integrated information from the *Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead* (NMFS 2011a) with more specificity than did the Washington management unit plan, NMFS used estuary data from the Oregon plan to fill some gaps for Washington populations. Owing to the complex nature of estuarine habitat, the Oregon management unit plan relied on some general limiting factors to describe issues

that salmonids face in the Columbia River estuary. One of these "catchall" factors is "physical habitat quality (impaired habitat complexity and diversity, including access to off-channel habitats)." This limiting factor was used to provide a general sense of the overall conditions faced by all salmon populations in the estuary.

**Step 4:** *Incorporated draft data dictionaries for hydropower, harvest, and hatchery concerns developed by the NMFS Northwest Fisheries Science Center into the crosswalk tables.*

This resulted in a more comprehensive list of limiting factors, or ecological concerns. NMFS Northwest Region staff then correlated the management unit plans' hydropower, harvest, and hatchery limiting factor terms to the relevant data dictionary terms and added a column to the crosswalk tables to display the threats associated with each of the ecological concern subcategories.

**Step 5:** *Populated the rest of population-level crosswalk tables (i.e., the hydropower, harvest, and hatchery rows) as described above.*

**Step 6:** *Developed stratum-level summary tables of limiting factors and incorporated them into Chapters 6 through 9 of the Lower Columbia River ESU recovery plan.*

The stratum-level summary tables organize the ecological concerns into six categories (tributary habitat, estuary habitat, hydropower, harvest, hatchery, and predation concerns), in most cases employing the broader ecological concern categories from the data dictionary, with a few exceptions where added specificity was desired (such was the case with peripheral and transitional habitats and direct mortality).

Because the stratum-level limiting factor tables are summaries, they do not include all the information contained in the population-level tables. NMFS selected ecological concerns for inclusion in the stratum-level limiting factor tables based on the severity and/or scope of impact on individual populations. For example, typically, only one or two populations in a given stratum experience the deleterious effects of obstructed passage because of the presence of a large dam, but those populations may experience these effects to a high degree. In this case, the ecological concern merits inclusion in the summary tables because of the severity of the impact, even though its scope is limited. The opposite may also hold true.

| LCR Coho ESU: Coast Stratum | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Grays | | Elochoman | | Mill Creek | | Youngs Bay | | Big Creek | | Clatskanie | | Scappoose | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | | | | | | | | | | | | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | | | | X | | X | | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | X | X | X | X | X | X | | | | | | | | |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | | | | | | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | | | | | | | X | | X | | X | | X |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | | | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | ? | | | | | | | | | | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | | | | | | | X | | X | | X | | X |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | | | | | | | X | | X | | X | | X |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | ? | | ? | | ? | | | **X** | | **X** | | **X** | | **X** |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | ? | | ? | | ? | | | X | | X | | X | | X |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | ? | | ? | | ? | | | | | | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | | **X** | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | X | | X | | X | | | | | | | | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | | | | | | | X | | X | | X | | X |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | | | | | | | **X** | | **X** | | **X** | | **X** |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | | | | | | | **X** | | **X** | | **X** | | **X** |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | | | | | | | **X** | | **X** | | **X** | | **X** |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | | | | | | | **X** | | **X** | | **X** | | **X** |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | | | | | | | X | | X | | X | | X |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | | | | | | | |

| LCR Coho ESU: Coast Stratum | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Grays | | Elochoman | | Mill Creek | | Youngs Bay | | Big Creek | | Clatskanie | | Scappoose | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | X | | X | | X | | | | | | | | | |
| | | | 8.1.a | ` | Dams | 6c, 6d | | | | | | | | | X | | X | | X | | X |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | | | | | | | X | | X | | X | | X | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | X | | X | | X | | | | | | | | | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | | | | | | X | X | X | X | X | X | X | X |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | | | | | | | X | | X | | X | | X |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | X | | X | | X | | | | | | | | | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | | | | | | | X | | X | | X | | X |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | | | | | | | X | | X | | X | | X | |
| | | | 9.4 | pH | | | | | | | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | X | | X | | X | | | | | | | | | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | | | | | | | X | | X | | X | | X | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | | | | | | | X | | X | | X | | X |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | X | | X | | X | | | | | | | | | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | | | | | | | X | | X | | X | | X |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | | | | | X | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | X | | X | | X | | | | | | | | | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | | | | | | | X | | X | | X | | X |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | | | | | | | X | | X | | X | | X | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | X | | X | | X | | X | | X | | X | | X |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | | | | | | | | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | X | | X | | X | | X | | X | | | |

## LCR Coho ESU: Cascade Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Clackamas | | Sandy | | Lower Cowlitz | | Coweeman | | Toutle (SF) | | Toutle (NF) | | Upper Cowlitz | | Lewis (EF) | | Lewis (NF) | | Salmon Creek | | Cispus | | Tilton | | Kalama | | Washougal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | X | | | | | | | | | | | | X | | | | X | | | | X | | X | | | | | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | ? | ? | | | | | | | ? | ? | | | ? | ? | ? | ? | ? | ? | | | ? | ? | ? | ? |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | X | | X | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | | | ? | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | | X | ? | | | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | | | | | ? | |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | | | ? | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## LCR Coho ESU: Cascade Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Clackamas | | Sandy | | Lower Cowlitz | | Coweeman | | Toutle (SF) | | Toutle (NF) | | Upper Cowlitz | | Lewis (EF) | | Lewis (NF) | | Salmon Creek | | Cispus | | Tilton | | Kalama | | Washougal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.4 | pH | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |

## LCR Coho ESU: Gorge Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Lower Gorge | | Upper Gorge/White Slamon | | Upper Gorge/Hood | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | **X** | | X | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | X | | | | X | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | X | X | | X |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | X | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | X | | | X | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | **X** | | | | **X** |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | | X | X |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | | X | X |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | **X** | | | | **X** |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | | | X | X |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | | | **X** | | **X** | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | | | **X** | | **X** | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | X | | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | | | X |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | **X** | | | | **X** |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | **X** | | | | **X** |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | **X** | | | | **X** |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | **X** | | | | **X** |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | | | X |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | |

## LCR Coho ESU: Gorge Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Lower Gorge | | Upper Gorge/White Slamon | | Upper Gorge/Hood | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | X | X | | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | X | | | | X |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | | | | | X | |
| | | | 8.1.c | Increased Sediment Quantity | Dam removal | | | | | X | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | X | X | | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | X | | | X | X |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | X | | | | X |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | X | X | | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | | | X |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | | | | | | |
| | | | 9.4 | pH | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | X | | | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | | | X | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | | X | X |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | X | | | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | | X | X |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | X | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | X | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | X | | | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | | | X |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | | | X | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | X | | | | X |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | | | X | |

| LCR Chinook ESU: Cascade Spring Stratum | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Sandy | | Upper Cowlitz | | Cispus | | Tilton | | Toutle | | Kalama | | Lewis (NF) | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | X | | X | | X | | X | | | | | | X | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | | | | | | | | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | | | | | | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | | | | | | | | | | | | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | | | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | ? | | ? | | ? | | | | | | ? | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | X | | X | | X | | X | | X | | X | | X |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | | | | | | | | | | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | | | | | | | | | | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | X | | | | | | | | | | | | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | ? | | ? | | | | | | | | ? | |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | ? | | ? | | ? | | | | | | ? | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | X | | X | | X | | X | | X | | X |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | | | | | | | | | | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | X | | | | | | | | | | | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | X | | | | | | | | | | | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | X | | | | | | | | | | | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | X | | | | | | | | | | | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | | | | | | | | | | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | | | | | | | |

| LCR Chinook ESU: Cascade Spring Stratum | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Sandy | | Upper Cowlitz | | Cispus | | Tilton | | Toutle | | Kalama | | Lewis | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | X | | X | | X | | X | | X | | X | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | X | X | | | | | | | | | | | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | X | | | | | | | | | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | | | X | | X | | X | | X | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | X | | | | | | | | | | | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | X | | | | | | | | | | | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | X | | X | | X | | X | | X | | X | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | | | | | | | | | | | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | X | | | | | | | | | | | | | |
| | | | 9.4 | pH | | | | | | | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | X | | X | | X | | X | | X | | X | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | | | | | | | | | | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | | | | | | | | | | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | X | | X | | X | | X | | X | | X | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | | | | | | | | | | | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | | | | | | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | X | | X | | X | | X | | X | | X | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | | | | | | | | | | | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | | | | | | | | | | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | X | | X | | X | | X | | X | | X | | X |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | X | | | | | | | | | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | X | | X | | X | | X | | X | | X | |

| LCR Chinook ESU: Gorge Spring Stratum | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Hood | | White Salmon | |
| | | | | | | | | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | X | | **X** | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | | |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | X | X | X | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | X | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | **X** | X | |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | X | X | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | **X** | | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | X | X | X | |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | | | | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | X | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | X | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | X | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | X | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | X | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | |

## LCR Chinook ESU: Gorge Spring Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Hood | | White Salmon | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | X | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | X | | | |
| | | | 8.1.c | Increased Sediment Quantity | Dam removal | | | | | X | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | X | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | X | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | X | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | X | | | |
| | | | 9.4 | pH | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | X | | X | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | X | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | X | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | X | X | |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | | |

| LCR Chinook ESU: Coastal Fall Stratum | | | | | | | | Youngs Bay | | Big Creek | | Clatskanie | | Scappoose | | Grays | | Elochoman | | Mill Creek | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | | | | | | | | | | | | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | X | | X | | | | | | | | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | | | | | | | X | | X | X | X | X |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | | | | | | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | X | | X | | X | | X | | | | | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | | | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | | | | | ? | | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | X | | X | | X | | X | | X | | X | | X |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | X | | X | | | | | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | X | | X | | | | | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | X | | X | | X | | X | | | ? | | | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | | X | | X | | X | | ? | | ? | | ? |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | | | | | | | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | | | | | | | X | | X | | X |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | X | | X | | X | | | | | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | X | | X | | X | | X | | | | | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | X | | X | | X | | X | | | | | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | X | | X | | X | | X | | | | | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | X | | X | | X | | X | | | | | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | X | | X | | X | | | | | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | | | | | | | |

| LCR Chinook ESU: Coastal Fall Stratum | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Youngs Bay | | Big Creek | | Clatskanie | | Scappoose | | Grays | | Elochoman | | Mill Creek | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | | | | | | | X | | X | X | X | X |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | X | | X | | X | | X | | | | | | | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | X | | X | | X | | X | | | | | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | | | | | X | | X | X | X | X |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | X | | X | | X | | X | | | | | | | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | X | | X | | X | | X | | | | | | | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | | | | | | | X | | X | X | X | X |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | X | | X | | X | | | | | | | | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | X | | X | | X | | X | | | | | | | | | |
| | | | 9.4 | pH | | | | | | | | | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | | | | | | | X | | X | X | X | X |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | X | | X | | X | | | | | | | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | X | | X | | X | | | | | | | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | | | | | | | X | | X | X | X | X |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | X | | X | | X | | | | | | | | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | | | | | | | | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | | | | | | | X | | X | X | X | X |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | X | | X | | X | | | | | | | | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | X | | X | | X | | | | | | | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | X | | X | | X | | X | | X | | X | | X | | X |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | | | | | | | | | | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | X | | X | | X | | X | | X | | X | | | |

| LCR Chinook ESU: Cascade Fall Stratum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Clackamas | | Sandy | | Lower Cowlitz | | Upper Cowlitz | | Toutle | | Coweeman | | Kalama | | Lewis (EF) | | Salmon Creek | | Washougal | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | X | | | | X | | | | | | | | | | | | | | | | | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | | | | X | | X | X | X | | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | X | | X | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | ? | ? | ? | ? | | | | | | | | | | | | | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | X | | X | | X | | X | | X | | X | | X | | X | X | X | X | X | X | X | X |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | | | | | | | | | | | | | | | | | | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | | | | | | | | | | | | | | | | | | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | X | | X | | ? | ? | ? | | | | | | | | | | | | | | | | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | | X | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | | ? | ? | ? | | | | | | | | | | | | | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | X | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.b | Reduced macrodetritral inputs | Dam reservoirs | 3a | | | X | | X | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | X | | X | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | X | | X | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | X | | X | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | X | | | | | | | | | | | | | | | | | | | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## LCR Chinook ESU: Cascade Fall Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Clackamas | | Sandy | | Lower Cowlitz | | Upper Cowlitz | | Toutle | | Coweeman | | Kalama | | Lewis (EF) | | Salmon Creek | | Washougal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | | | X | X | X | X | X | | X | X | X | X | X | X | X | X | X | X |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | X | X | X | X | | | | | | | | | | | | | | | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | X | | X | | | | | | | | | | | | | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | | | | | X | | X | | X | | X | | X | | X | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | X | X | | X | | | | | | | | | | | | | | | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | X | X | | X | | | | | | | | | | | | | | | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | | | | | | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | | | X | X | X | X | X | | X | | X | | X | | X | | X | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | X | | | | | | | | | | | | | | | | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | X | | X | | | | | | | | | | | | | | | | | |
| | | | 9.4 | pH | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | | | | | | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | | | X | X | X | X | X | | X | | X | | X | | X | | X | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | X | | | | | | | | | | | | | | | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | X | | | | | | | | | | | | | | | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | | | X | X | X | X | X | | X | | X | | X | | X | | X | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | X | | | | | | | | | | | | | | | | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | | | X | X | X | X | X | | X | | X | | X | | X | | X | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | X | | | | | | | | | | | | | | | | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | X | | | | | | | | | | | | | | | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | | | | | | | | | | | | | | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |

| LCR Chinook ESU: Gorge Fall Stratum | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Lower Gorge | | Upper Gorge | | Hood | | White Salmon | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | X | | X | | X | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | | | | | | |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | X | | X | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | X | | X | | X | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | X | | X | | X | X | X |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | X | X | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | X | X | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | X | | X | | X | | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | X | X | X | X | X | |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | X | X | X | X | X | X | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | X | X | X | X | X | X | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | X | X | X | X | X | | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | X | X | X | X | X | | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | | | | | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | X | | X | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | X | | X | | X | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | X | | X | | X | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | X | | X | | X | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | X | | X | | X | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | X | | X | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | |

| LCR Chinook ESU: Gorge Fall Stratum | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Lower Gorge | | Upper Gorge | | Hood | | White Salmon | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | | | | | | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | X | | X | | X | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | | | | | X | | | |
| | | | 8.1.c | Increased Sediment Quantity | Dam removal | | | | | | | | | X | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | | | | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | X | | X | | X | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | X | | X | | X | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | | | | | | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | X | | X | | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | | | | | X | | | |
| | | | 9.4 | pH | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | | | | | | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | X | | X | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | X | X | X | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | | | | | | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | X | X | X | | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | X | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | | | | | | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | X | | X | | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | X | | X | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | X | | X | | X | | X |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | X | | X | | X | |

# LCR Chinook ESU: Cascade Late Fall Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Sandy | | Lewis (NF) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | X | | | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | X | X |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | X | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | **X** | **X** | **X** |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | **X** | | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | | |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | **X** | | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | X |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | **X** | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | **X** | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | **X** | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | **X** | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | |

| LCR Chinook ESU: Cascade Late Fall Stratum | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Sandy | | Lewis (NF) | |
| | | | | | | | | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | X | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | X | X | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | X | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | X | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | X | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | X | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | X | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | X | | | |
| | | | 9.4 | pH | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | X | X |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | X | X |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | X | X |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | X | | X |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | | |

| LCR Chum ESU: Coast Stratum | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Grays | | Elochoman | | Mill Creek | | Youngs Bay | | Big Creek | | Clatskanie | | Scappoose | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | | | | | | | | | | | | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | | | | X | | X | | | | X | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | X | | | | | | | | | | | |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | | | | | | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | | | | | | | | | | | | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | | | X | | X | | X | | X |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | | | | | | | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | | | | | | | | | | | | | |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | | | | | | | X | | X | | X | | X |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | | | | | | | X | | X | | X | | X |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | | | | | | | **X** | | **X** | | **X** | | **X** |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | | | | | | | | | | | | |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | | | | | | | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | | | | | | | | | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | **X** | | **X** | | **X** | | | | | | | | | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | | | | | | | | | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | | | | | | | | | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | X | | X | | X | | | | | | | | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | | | | | | | | | | | | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | | | | | | | **X** | | **X** | | **X** | | **X** |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | | | | | | | **X** | | **X** | | **X** | | **X** |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | | | | | | | **X** | | **X** | | **X** | | **X** |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | | | | | | | **X** | | **X** | | **X** | | **X** |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | | | | | | | X | | X | | X | | X |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | | | | | | | |

| LCR Chum ESU: Coast Stratum | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Grays | | Elochoman | | Mill Creek | | Youngs Bay | | Big Creek | | Clatskanie | | Scappoose | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | | X | | X | | X | | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | | X | | X | | X | | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | X | | X | | X | | | | | | | | | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | | | | | | | X | | X | | X | | X |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | | | | | | | X | | X | | X | | X | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | | | | | | | | | | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | | | | | | | X | | X | | X | | X |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | | | | | | | X | | X | | X | | X |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | X | | X | | X | | | | | | | | | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | | | | | | | X | | X | | X | | X |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | | | | | | | X | | X | | X | | X | |
| | | | 9.4 | pH | | | | | | | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | X | | X | | X | | | | | | | | | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | | | | | | | X | | X | | X | | X | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | | | | | | | X | | X | | X | | X |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | X | | X | | X | | | | | | | | | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | | | | | | | X | | X | | X | | X |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | | | | | | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | X | | X | | X | | | | | | | | | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | | | | | | | X | | X | | X | | X |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | | | | | | | X | | X | | X | | X | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | | | | | | | | | | | | | |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | | | | | | | | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | | | | | | | | | | | | |

## LCR Chum ESU: Cascade Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Clackamas | | Sandy | | Cowlitz | | Lewis | | Salmon Creek | | Kalama | | Washougal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | | | | | | | | | | | | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | X | | X | | | | | | | | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | | | | | | | | | | | | |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | | | | | | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | | | | | | | | | | | | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | X | | X | | | | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | ? | ? | | | | | ? | ? | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | | | | | | | | | | | | | |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | | | | | | | | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | | | | | | | | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | X | | X | | | | | | | ? | | | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | | | | | | | | | | | | | |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | | | | | | | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | | | | | X | | X | | X | | X | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | | | | | X | | X | | X | | X | | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | | | | | X | | X | | X | | X | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | | | | | X | | X | | X | | X | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | | | X | | X | | X | | X | | X |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | | | | | | | | | | | | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | X | | X | | | | | | | | | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | X | | X | | | | | | | | | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | X | | X | | | | | | | | | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | X | | X | | | | | | | | | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | X | | | | | | | | | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | | | | | | | |

## LCR Chum ESU: Cascade Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Clackamas | | Sandy | | Cowlitz | | Lewis | | Salmon Creek | | Kalama | | Washougal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | | **X** | | **X** | **X** | X | **X** | X | **X** | X | **X** | X | **X** | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | | **X** | | **X** | **X** | X | **X** | X | **X** | X | **X** | X | **X** | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | | | **X** | | X | | | | **X** | | **X** | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | **X** | | **X** | | | | | | | | | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | X | | X | | | | | | | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | | | **X** | | **X** | | **X** | | | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | X | | X | | | | | | | | | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | X | | X | | | | | | | | | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | | | **X** | | X | | | | **X** | | **X** | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | **X** | | **X** | | | | | | | | | | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | X | | X | | | | | | | | | | | |
| | | | 9.4 | pH | | | | | | | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | | | **X** | | X | | X | | **X** | | X | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | X | | | | | | | | | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | **X** | | **X** | | | | | | | | | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | | | **X** | | X | | X | | **X** | | X | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | **X** | | **X** | | | | | | | | | | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | | | | | | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | | | **X** | | X | | X | | **X** | | X | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | **X** | | **X** | | | | | | | | | | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | X | | | | | | | | | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | | | | | | | | | | | | | |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | | | | | | | | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | | | | | | | | | | | | | | |

## LCR Chum ESU: Gorge Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Lower Gorge | | Upper Gorge | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | X | X |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | | |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | X | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | X | X | X |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | | | |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | X | | X |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | | | |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | X | | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | X | | X |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | X | | X |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | X | | X |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | X | | X |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | X |
| | | | 6.4 | Nearshore Conditions | | | | | | | |

## LCR Chum ESU: Gorge Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Lower Gorge | | Upper Gorge | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | X | | X |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | X | | X |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | X | | X |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b | Sediment | | | | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | X |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | | | | |
| | | | 9.4 | pH | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | X | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | X |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | X |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | X |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | X | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | | | |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | | | | |

## LCR Steelhead DPS: Cascade Winter Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Clackamas | | Sandy | | Lower Cowlitz | | Coweeman | | Toutle (SF) | | Toutle (NF) | | Upper Cowlitz | | Cispus | | Tilton | | Kalama | | Lewis (NF) | | Lewis (EF) | | Salmon Creek | | Washougal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | X | | X | | | | | | | | | | X | | X | | X | | | | X | | | | | | | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | X | | X | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? | | ? |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | X | | X | | | | | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | | | | | | | | | | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | | X | ? | ? | | | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? | ? |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | ? | ? | ? | ? | ? | ? | ? | ? | | | | | | | | | | | ? | ? | | | ? | ? |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e, 6f | Food, Channel stability, habitat diversity, key habitat, flow | | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

## LCR Steelhead DPS: Cascade Winter Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Clackamas | | Sandy | | Lower Cowlitz | | Coweeman | | Toutle (SF) | | Toutle (NF) | | Upper Cowlitz | | Cispus | | Tilton | | Kalama | | Lewis (NF) | | Lewis (EF) | | Salmon Creek | | Washougal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | X | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | | | | | | ? | | ? | | | | | | | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b, 6c | Sediment | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.4 | pH | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | | X | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | X | | X | | X | | X | | X | | X | | X | | X | | | | X | | X | | X | | X | | |

## LCR Steelhead DPS: Gorge Winter Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Lower Gorge | | Upper Gorge | | Hood | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | X | | X | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | X | | X | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | | | | | | |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | X | X | X | X |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | X | | X | | X |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | X | | X | | X |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | X | X |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | X | | X | X | X |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | **X** | | **X** | | **X** |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | | X | X | X | X | X |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | **X** | | **X** | | **X** | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | | **X** | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | | | | | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | X | | X | | X |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | **X** | | **X** | | **X** |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | **X** | | **X** | | **X** |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | **X** | | **X** | | **X** |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | **X** | | **X** | | **X** |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | X | | X | | X |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | |

## LCR Steelhead DPS: Gorge Winter Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Lower Gorge | | Upper Gorge | | Hood | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | | | | | | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | X | | X | | X |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | | | | | X | |
| | | | 8.1.c | Increased Sediment Quantity | Dam removal | | | | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | X | | X | X | X |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | X | | X | | X |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b, 6c | Sediment | | | | | | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | X | | X | | X |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | | | | | X | |
| | | | 9.4 | pH | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | | | | | | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | X | | X | | X | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | X | | X | X | X |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | | | | | | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | X | | X | X | X |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | X | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | X | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | | | | | | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | X | | X | | X |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | X | | X | | X | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | | | X | | X |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | X | | X | | X |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | X | | X | | X | |

## LCR Steelhead DPS: Cascade Summer Stratum

| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Kalama | | Lewis (NF) | | Lewis (EF) | | Washougal | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | | | X | X | | | | |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | X | X | X | X | X | X | X | X |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | | | | | | |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | | | | | | | |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | | | | | | | ? | ? |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | X | | X | | X | | X |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | | | | | | | |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | | | | | | | |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | | | | | | | |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | ? | | ? | | ? | | ? | |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | X | | X | | X | | X | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | X | | X | | X | | X | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e | Food, Channel stability, habitat diversity, key habitat, flow | | X | | X | | X | | X |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | | | | | | | |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | | | | | | | |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | | | | | | | |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | | | | | | | |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | | | | | | | |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | | | | | | | |
| | | | 6.4 | Nearshore Conditions | | | | | | | | | | | |

| LCR Steelhead DPS: Cascade Summer Stratum | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Kalama | | Lewis (NF) | | Lewis (EF) | | Washougal | |
| | | | | | | | | Trib | Est | Trib | Est | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | X | | | | X | | X | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | | | | | | | |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | | | | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | | | | | X | | X | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | | | | | | | |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | | | | | | | |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b, 6c | Sediment | X | | | | X | | X | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | | | | | | | |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | | | | | | | | |
| | | | 9.4 | pH | | | | | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | X | | | | X | | X | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | | | | | | | | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | | | | | | | |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | X | | | | X | | X | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | | | | | | | |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | | | | | | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | X | | | | X | | X | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | | | | | | | |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | | | | | | | | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | | | | | | | |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | | X | | X | | X | | X |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | | | X | | X | | X | |

| LCR Steelhead DPS: Gorge Summer Stratum | | | | | | | | Wind | | Hood | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Trib | Est | Trib | Est |
| 1 | Habitat Quantity | Connectivity, Access, Structure, Simplification, Availability | 1.1 | Anthropogenic Barriers (dams) | Large Dams | 4a, 4b, 6g | Obstructions | X | X | X | X |
| | | | 1.2 | Anthropogenic Barriers (other) | Hatchery Weirs, Road Crossings, Small Dams, Diversions | 4c, 4d, 4e | Obstructions | | | | |
| | | | 1.3 | Natural Barriers | Water Falls, Sand Bar, Bar Breach, Log Jams, Steep Gradient | | Obstructions | | | | |
| 2 | Direct Mortality | Predation, Disease, Species Interactions | 2.1 | Turbine/bypass mortality | Dams | | | | | | |
| | | | 2.2 | Predation | | 8a, 8b, 8c, 8d | Predation | X | X | | |
| | | | 2.2.a | Predation (non-salmonid fish, marine mamals) | Dams | 8a, 8d | | | | X | X |
| | | | 2.2.b | Predation (birds) | Land use | 8b | | | | | X |
| | | | 2.2.c | Predation (hatchery fish) | Hatcheries | 8c | | | | | |
| | | | 2.3 | Pathogens | Disease, Sea Lice | | Pathogens | ? | ? | | |
| | | | 2.4 | Harvest | Consumptive, targeted fishery/gillnet fisheries targeted at other species | 7a, 7b | Harvest | | X | | X |
| 3 | Toxic Contaminants | Pollution | 3.1 | Water | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | | X | X |
| | | | 3.2 | Biota | Agricultural Chemicals, Urban and Industrial Practices | 9c, 9d | Chemicals | | | X | X |
| 4 | Food | Competition, Prey Availability, Species Interactions | 4.1 | Altered Primary Productivity | Dam Reservoirs | 3a, 3b | Food | | | | **X** |
| | | | 4.2 | Competition | Smolts from all Columbia Basin hatcheries | 1a | Competition | ? | ? | X | X |
| | | | 4.3 | Altered Prey Composition and Diversity | Prey species/other species harvest | | Food | | | | |
| 5 | Riparian Condition | Impaired Riparian Function/Condition, Microclimate, Lack of Shade | 5.1 | Riparian Condition | Past and/or currrent land use practices | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | |
| | | | 5.2 | LWD Recruitment | | 6e, 6f | Channel stability, Flow, Habitat Diversity | **X** | | **X** | |
| | | | 5.2.b | LWD Recruitment | Past and/or currrent land use practices | | | | | | |
| | | | 5.2.a | LWD Recruitment | Dams | | | | | | |
| 6 | Peripheral and Transitional Habitats | High quality over-winter rearing habitat, Habitat Diversity, (Key) Habitat Quantity/Quality, Refugia Habitat | 6.1 | Side Channel and Wetland Conditions | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | |
| | | | 6.2 | Floodplain Condition | Past and/or currrent land use practices/transportation corridor | 6e, 6f | Channel stability, habitat diversity, key habitat | **X** | | **X** | |
| | | | 6.3 | Estuary Conditions | | 3a, 3b, 5b, 6c, 6e, 6f | Food, Channel stability, habitat diversity, key habitat, flow | | X | | |
| | | | 6.3.a | Competition from hatchery smolts | Hatcheries | 1a | | | | | X |
| | | | 6.3.b | Reduced macrodetrital inputs | Dam reservoirs | 3a | | | | | **X** |
| | | | 6.3.c | Increased microdetrital inputs | Dam reservoirs | 3b | | | | | **X** |
| | | | 6.3.d | Altered plume dynamics | Dams | 5b | | | | | **X** |
| | | | 6.3.e | Impaired sediment/sandf routing | Dams | 6c | | | | | **X** |
| | | | 6.3.f | Estuary habitat quality (complexity and diversity) | Dams | 6e | | | | | X |
| | | | 6.4 | Nearshore Conditions | | | | | | | |

| LCR Steelhead DPS: Gorge Summer Stratum | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ID | Ecological Concern | Alternate Terms | ID | Ecological Concern Sub-Category | Threat | OR Plan Code | WA Plan Terms | Wind | | Hood | |
| | | | | | | | | Trib | Est | Trib | Est |
| 7 | Channel Structure and Form | Channel Conditions, Channel Form, Channel morphology, Channel Instability, Channel Stability, Loss of Spawning Substrate due to high flow, Bedload Movement | 7.1 | Bed and Channel Form | Past and/or currrent land use practices/transportation corridor | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X |
| | | | 7.2 | Instream Structural Complexity | Past and/or currrent land use practices | 6e, 6f, 6g, 5b | Channel stability, habitat diversity, key habitat, flow | X | X | X | X |
| 8 | Sediment Conditions | Sediment, Stream Spawning Habitat, Spawning Gravel, Beach Spawning Habitat (lake), Substrate, Benthic Habitat | 8.1 | Sediment Quantitiy | | 6a, 6b, 6c, 6d | Sediment | X | | | |
| | | | 8.1.a | Decreased Sediment Quantity | Dams | 6c, 6d | | | | | X |
| | | | 8.1.b | Increased Sediment Quantity | Past and/or currrent land use practices/transportation corridor | 6a, 6b | | | | X | |
| | | | 8.1.c | Increased Sediment Quantity | Dam removal | | | | | | |
| 9 | Water Quality | | 9.1 | Temperature | | 9a, 9b | Temperature | X | | | |
| | | | 9.1.a | Temperature (land use) | Land uses that impair riparian function/decrease streamflow | 9a | | | | X | X |
| | | | 9.1.b | Temperature (dam reservoirs) | Large dam reservoirs | 9b | | | | | X |
| | | | 9.2 | Oxygen | Agricultural Chemicals, Urban and Industrial Practices | | Oxygen | | | | |
| | | | 9.3 | Turbidity | | 6a, 6b, 6c | Sediment | X | | | |
| | | | 9.3.a | Decreased Turbidity (dams) | Dams | 6c | | | | | X |
| | | | 9.3.b | Increased Turbidity (land use) | Land use/rural roads | 6a, 6b | | | | X | |
| | | | 9.4 | pH | | | | | | | |
| | | | 9.5 | Salinity | | | Salinity | | | | |
| 10 | Water Quantity | Changes in Flow Regime, Spring Freshets, Piped Outfalls of Surface and Ground Water, Withdrawals, Flow-Related Plume Changes | 10.1 | Altered Hydrology | | 5a, 5b, 5c | Flow | X | | | |
| | | | 10.1.a | Altered Hydrology | Past and/or currrent land use practices/transportation corridor | 5c | | | | X | |
| | | | 10.1.b | Altered Hydrology | Dams | 5a, 5b | | | | X | X |
| | | | 10.2 | Decreased Water Quantity | | 5a, 5b, 5d, 5e, 5f | Flow | X | | | |
| | | | 10.2.a | Decreased Water Quantity | Low-head hydro diversions, dams | 5a, 5b | | | | X | X |
| | | | 10.2.b | Decreased Water Quantity | Irrigation and municipal withdrawals | 5d, 5e | | | | X | |
| | | | 10.2.c | Decreased Water Quantity | Hatchery withdrawals | 5f | | | | | |
| | | | 10.3 | Altered Flow Timing | | 5b, 5c | Flow | X | | | |
| | | | 10.3a | Altered Flow Timing | Dams | 5b | | | | | X |
| | | | 10.3.b | Altered Flow Timing | Land use | 5c | | | | X | |
| 11 | Population Diversity | Genetic drift, loss of genetic diversity, artificail selection by hatchery personnel interbreeding | 11.1 | Impaired abundance and diversity (targeted fishing) | Consumptive, targeted fishery | 7a | Harvest | | | | X |
| | | | 11.2 | Impaired abundance and diversity (non-targeted fishing) | Gill net fisheries targeted at other species | 7b | Harvest | X | | | |
| | | | 11.3 | Impaired productivity and diversity | Stray hatchery fish interbreeding with wild fish | 7c | | | | X | |