Section B – 1: *The nature and extent of threats being addressed by the conservation effort are described*

Introduction

The Oregon Department of Environmental Quality (DEQ) has evaluated stream conditions (nature and extent) within the Coastal Coho Evolutionarily Significant Unit (ESU) related to the following factors for decline:

- Water temperature
- Dissolved oxygen
- pH
- Stream fertility (nutrients)
- Sediment and substrate
- Biological conditions (fish and macroinvertebrate communities)
- *Toxic Chemicals*

Toxic chemicals, while listed as a potential factor for decline in the 1997 CSRI document (State of Oregon 1997), have not been assessed due to the high cost and unknown nature of what toxic chemicals to test for. The episodic use and presence of toxic chemicals also makes it easy to sample when they are not present, and thus make mistaken conclusions about their use. Changes in other parameters, particularly the biological communities, may provide some indication of exposure to toxic chemicals.

The objectives of the monitoring program are four-fold:

1. Characterize the status of stream conditions for selected parameters identified as factors for decline within the ESU.
2. Evaluate trends in the parameters identified as factors for decline within the ESU.
3. Assess which parameters pose the greatest stress or risk to in-stream biological communities.
4. Develop a monitoring program that will be able to evaluate the effectiveness of management and conservation programs.

Only data from streams within the coho distribution area of the Coastal Coho ESU are analyzed for this report. Results have been summarized for the entire ESU, for four smaller monitoring units within the ESU, and for major land use classes within the ESU. A description of the ESU and the sub-units assessed is detailed below.

Monitoring Area Description

The Oregon Coastal Coho Evolutionarily Significant Unit (ESU):

The Oregon Coastal Coho ESU encompasses one of six distinct west coast coho salmon groups identified by the National Oceanic and Atmospheric Administration Fisheries service (NOAA Fisheries) in 1995. The region extends from the Lower Columbia River in the north to the Sixes River in the south. It runs along the crest of the Coast Range to the Siuslaw River where it extends eastward to the headwaters of the Umpqua River in the Cascade Mountains. The area covers approximately 10,976 square miles and over 9,655 miles of stream network. For assessment purposes the ESU was divided into four Monitoring Units: the North Coast (NOCO), Mid-Coast (MICO), Mid-South Coast (MISO) and Umpqua (UMPQ) (Figure 1). The Monitoring Units are further subdivided into nineteen independent coho populations, which are discussed in ODFW's coho population assessment.

The ESU conditions were also evaluated by land use. The categories were divided into public sector lands (State Forested (SF) and Federal Forested (FF)) and private sector lands (Private Industrial Forest (PIF), Private Non-Industrial Forest (PNIF), Agriculture (AG) and Urban). Across the region, public sector lands accounted for 46% of land use, while private sector lands represented 54%.

The Oregon Coast ESU includes portions of four ecoregions (Omernik 2004): the Coast Range (83%), Willamette Valley (8%), Cascades (8%) and Klamath (1%). The lithography of the region is dominated by highly erodible, sedimentary geology with pockets of erosion resistant igneous geology located in the North Coast, Mid-Coast and Umpqua monitoring units

Finally, the ESU was divided into two geological categories, "Erodible" and "Resistant"(Dave Cole, per. comm) (Figure 2). The erodible geology contains alluvium, argillite and slate, glacial drift, lake sediment and playa, landslide, meta-sedimentary phyllite, sandstone, shale and mudstone, and siltstone. The resistant geology contains calc-alkaline intrusive, calc-alkaline meta-volcanic, felsic pyroclastic, mafic gneiss, mafic intrusive, mafic pyroclastic, mafic volcanic flow, and ultramafic (Walker and Macleod, 1991).

Coho Distribution:

The coho distribution is the portion of Oregon Coast ESU known to be used by coho salmon for passage, spawning or rearing. Unless otherwise stated, analysis in this report is constrained to streams contained within the coho distribution across the Oregon Coast ESU. This portion of the ESU contains approximately 3,500 perennial wadeable stream miles characterized by small, highly erodible, low elevation, low gradient streams (Table 1). Thirty five percent of the land in this area is publicly owned and 65% privately owned. The area also crosses portions of the Coast Range, Willamette Valley, Cascades, and Klamath ecoregions.

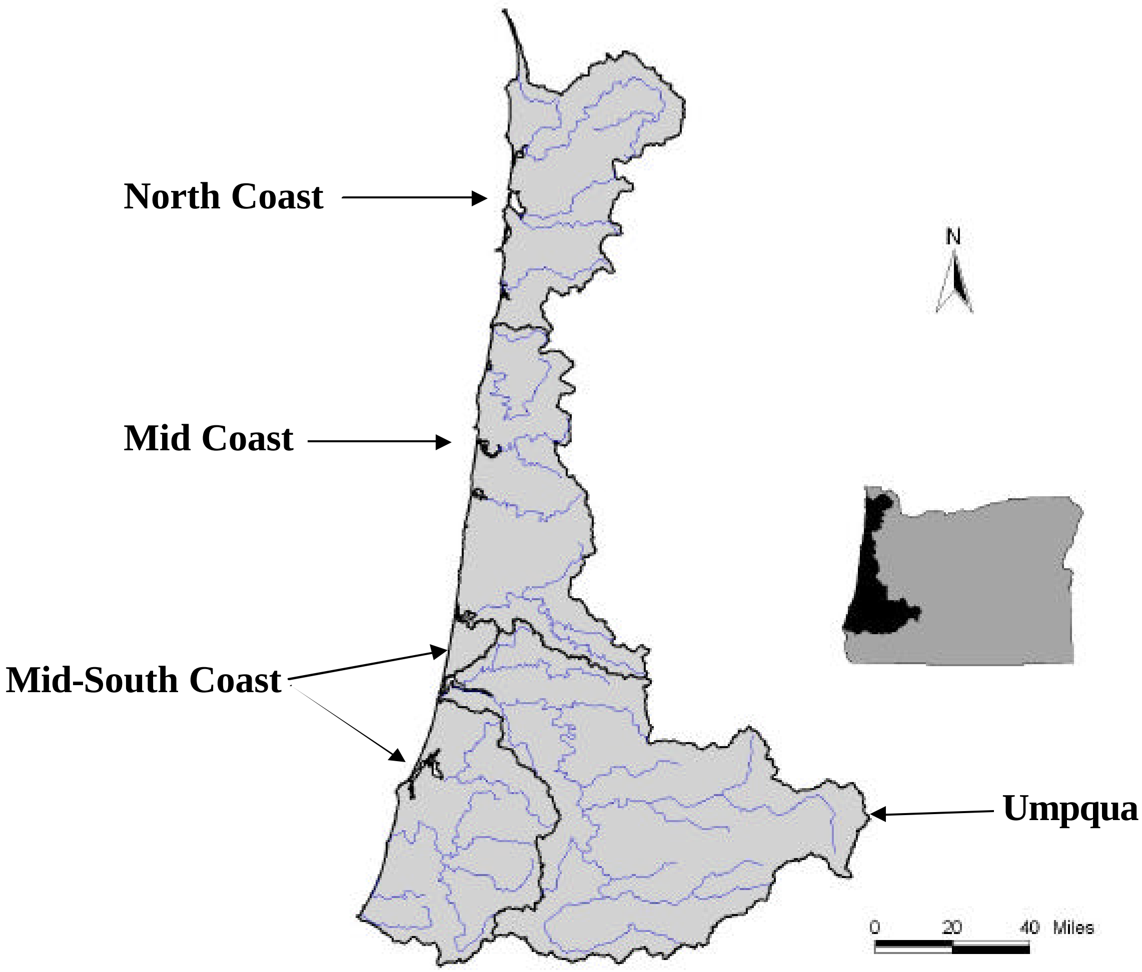


Figure 1. The Oregon Coast Evolutionarily Significant Unit (ESU) with the four monitoring units: North Coast (NOCO), Mid-Coast (MICO), Mid-South Coast (MISO) and Umpqua (UMPQ).

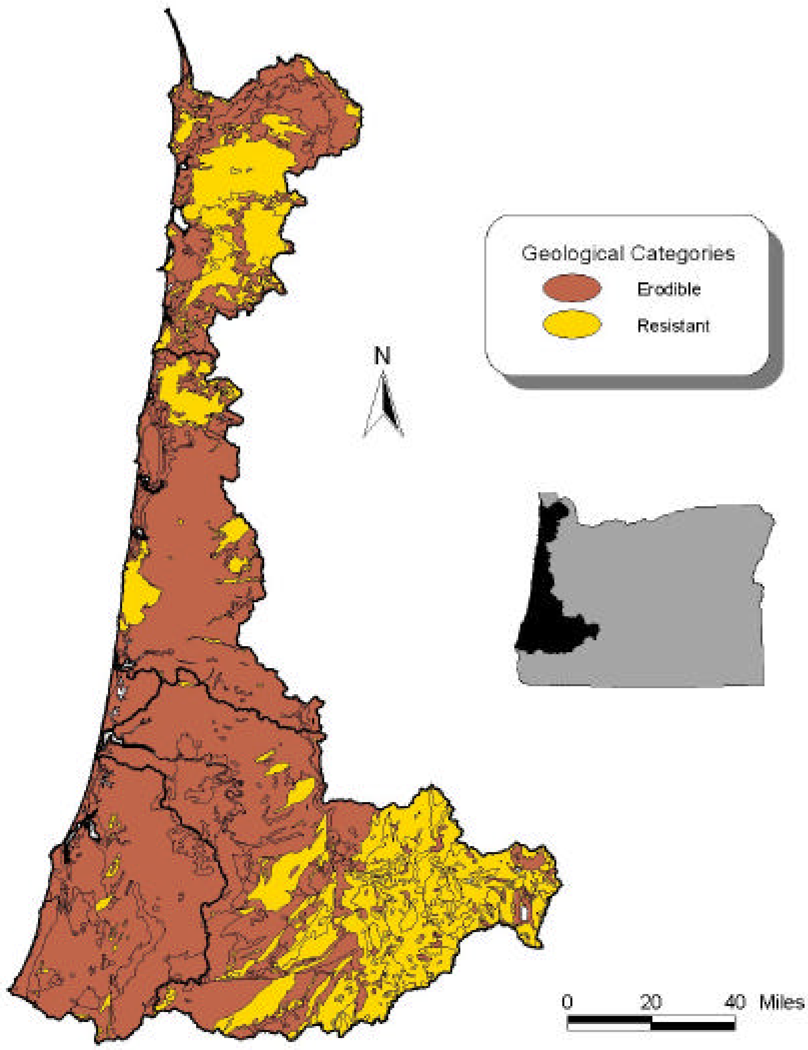


Figure 2. Erodible and Resistant geology within the Coastal Coho ESU.

Table 1. Physical attributes and their extent for the coho distribution area within the Coastal Coho ESU.

Attribute	Extent	
Lithography (% of stream miles)	Resistant	22
	Erodible	78
Elevation (Feet) Percentiles	25th	174
	50th	418
	75th	1019
	Range	14-2193
Map Slope (%) Percentiles	25th	<1
	50th	1
	75th	3
	Range	<1-17
Watershed Area above sampling point (square miles) Percentiles	25th	1.7
	50th	2.9
	75th	9.4
	Range	<1-158
Land Use (% of stream miles)	SF	12
	FF	23
	PIF	27
	PNIF	14
	AG	18
	URBAN	6
SF = State Forested; FF = Federal Forested; PIF = Private Industrial Forest; PNIF = Private Non-industrial Forest; AG = Agricultural		

Land Use:

Land use categories were determined using three Geographic Information Systems (GIS) coverages: State Zoning maps, United States Geological Survey (USGS) National Land Cover Database, and State Ownership maps. Land use for each site was assigned by identifying the dominant land use within a 200 foot radius around 121 randomly selected stream sites. Six categories of land use were assigned: State Forested (SF), Federal Forested (FF), Private Industrial Forest (PIF), Private Non-Industrial Forest (PNIF), Agriculture (AG) and Urban. The physical attributes associated with the land use categories within the Coastal Coho ESU are shown in Table 2.

Table 2: Selected physical attributes of land use classifications.

Land use		SF	FF	PIF	PNIF	AG	Urban
Lithography (% of stream miles)	Resistant	34	28	24	0	19	Insufficient data
	Erodible	66	82	76	100	81	
Elevation (Feet) (Percentile)	25^{th}	134	267	155	21	21	
	50^{th}	460	573	683	107	245	
	75th	873	1024	1053	472	642	
	Range	134-1308	79-2193	14-1838	21-1153	21-1842	
Map Slope (%) (Percentile)	25^{th}	<1	<1	<1	<1	<1	
	50^{th}	1	2	2	<1	<1	
	75th	2	3	8	1	1	
	Range	<1-17	<1-17	<1-11	<1-4	<1-6	
Watershed Area (Square miles) (Percentile)	25^{th}	3.3	1.6	<1	2.6	2.6	
	50^{th}	3.6	2.3	2.2	12.4	2.9	
	75th	11.6	8.5	7.0	43.2	6.1	
	Range	<1-41	<1-133.5	<1-158.5	1.9-61.1	1.7-42.9	
SF = State Forested; FF = Federal Forested; PIF = Private Industrial Forest; PNIF = Private Non-industrial Forest; AG = Agricultural							

North Coast Monitoring Unit (NOCO):

The North Coast Monitoring Unit extends from the Lower Columbia River in the north to Neskowin Creek in the south and follows the crest of the Coast Range to the east. It is the smallest monitoring area in the ESU covering approximately 1,918 square miles. Within the coho distribution in this unit, there are 740 perennial wadeable stream miles. This unit is entirely contained within the Coast Range Ecoregion and contains a pocket of erosion resistant geology east of Tillamook (Table 3). The areas surveyed tended to have slightly larger watersheds with steeper gradients and lower elevations than the ESU coho distribution as a whole. Thirty eight percent of the land in the North Coast Monitoring unit is publicly owned and 62% is privately owned. State Forest was the dominant land use in the coho distribution followed by Urban and Private Non-industrial land uses.

Table 3. Physical attributes and their extent for the North Coast Monitoring Unit.

Attribute	Extent	
Lithography (% of stream miles)	Resistant	28
	Erodible	72
Elevation (Feet) Percentiles	25th	86
	50th	416
	75th	755
	Range	29-1308
Map Slope (%) Percentiles	25th	<1
	50th	2
	75th	3
	Range	<1-17
Watershed Area above sampling point (Square miles) Percentiles	25th	1.8
	50th	4.2
	75th	13.5
	Range	<1-55.6
Land Use (% of stream miles)	SF	28
	FF	10
	PIF	17
	PNIF	21
	AG	1
	URBAN	23
SF = State Forested; FF = Federal Forested; PIF = Private Industrial Forest; PNIF = Private Non-industrial Forest; AG = Agricultural		

Mid-Coast Monitoring Unit (MICO):

The Mid-Coast Monitoring Unit runs from the Salmon River in the north to the Siuslaw River in the south and east along the crest of the Coast Range. It is the second largest monitoring area in the ESU covering approximately 2,203 square miles and has 1,034 wadeable stream miles, the largest number of stream miles within the coho distribution (Table 4). The area is dominated by erodible geology. The watershed areas in the region were in the same range as the ESU coho distribution, but tended to be slightly smaller and less steep overall. The elevation covered a greater range than other monitoring areas. The Mid-Coast Monitoring Unit is contained within the Coast Range and a small fragment of the Willamette Valley ecoregions. Sixty five percent of the land in the area is publicly owned and 35% privately owned. State Forest is the dominant land use followed by Private Industrial Forest and Federal Forest uses. There are no agricultural or urban land use designations assigned to survey streams in this monitoring unit.

Table 4. Physical attributes and their extent for the Mid-Coast Monitoring Unit.

Attribute	Extent	
Lithography (% of stream miles)	Resistant	9
	Erodible	91
Elevation (Feet) Percentiles	25th	180
	50th	299
	75th	529
	Range	14-1838
Map Slope (%) Percentiles	25th	<1
	50th	1
	75th	3
	Range	<1-11
Watershed Area above sampling point (Square miles) Percentiles	25th	<1
	50th	2.5
	75th	5.7
	Range	<1-158.5
Land Use (% of stream miles)	SF	37
	FF	28
	PIF	27
	PNIF	8
	AG	0
	URBAN	0
SF = State Forested; FF = Federal Forested; PIF = Private Industrial Forest; PNIF = Private Non-industrial Forest; AG = Agricultural		

Mid-South Coast Monitoring Unit (MISO):

The Mid-South Coast Monitoring Unit is the third largest of the four monitoring areas. It covers approximately 2,199 square miles but contains only 401 wadeable streams miles within the coho distribution. The area is bisected in the north by the Umpqua monitoring unit. The northern portion forms a triangle that extends from the Siuslaw River east to Sweet Creek and then south-west to the mouth of the Umpqua River. The southern section begins below the Umpqua River and extends east to approximately the Coos-Douglas county line and south to the Sixes River. The area is entirely within the Coast Range ecoregion except for a small fragment in the Klamath Mountain ecoregion and is dominated by erodible geology. Forty-six percent of the land is public and the remaining fifty-four percent is private. State Forest is the dominant land use followed by Agriculture and Private Industrial Forest uses (Table 5).

Table 5. Physical attributes and their extent for the Mid-South Coast Monitoring Unit.

Attribute	Extent	
Lithography (% of stream miles)	Resistant	4
	Erodible	96
Elevation (Feet) Percentiles	25th	98
	50th	187
	75th	434
	Range	21-1935
Map Slope (%) Percentiles	25th	<1
	50th	1
	75th	2
	Range	<1-17
Watershed Area above sampling point (Square miles) Percentiles	25th	1.7
	50th	3.3
	75th	6.0
	Range	<1-78.5
Land Use (% of stream miles)	SF	32
	FF	14
	PIF	24
	PNIF	5
	AG	25
	URBAN	0
SF = State Forested; FF = Federal Forested; PIF = Private Industrial Forest; PNIF = Private Non-industrial Forest; AG = Agricultural		

Umpqua Monitoring Unit (UMPQ):

The Umpqua Monitoring Unit is the largest of the monitoring areas covering approximately 4,656 square miles and 633 wadeable stream miles. It fans eastward from the mouth of the Umpqua River to its headwaters in the Cascade Mountains and south to Cow Creek. The western portion of the monitoring area is primarily erodible geology but transitions to resistant geology moving eastward into the Cascades (Table 6). Seventy-five percent of the region was classified as private land and 25% public. Agriculture was the dominant land use followed by Private Industrial Forest and Federal Forest. No State Forested or Private Non-industrial Forest land uses were surveyed from this region.

Table 6. Physical attributes and their extent for the Umpqua Monitoring Unit

Attribute	**Extent**	
Lithography (% of stream miles)	Resistant	42
	Erodible	58
Elevation (Feet) Percentiles	25th	585
	50th	1114
	75th	1153
	Range	107-2102
Map Slope (%) Percentiles	25th	<1
	50th	2
	75th	4
	Range	<1-11
Watershed Area above sampling point (Square miles) Percentiles	25th	1.8
	50th	4.5
	75th	10.9
	Range	<1-61.7
Land Use (% of stream miles)	SF	0
	FF	25
	PIF	35
	PNIF	0
	AG	37
	URBAN	3

SF = State Forested; FF = Federal Forested; PIF = Private Industrial Forest; PNIF = Private Non-industrial Forest; AG = Agricultural

Data Sources & Monitoring Design

Three main sources of data have been used to evaluate water quality conditions in the Coastal Coho ESU and the subunits described above: 1) long-term ambient water quality monitoring sites; 2) probabilistic or randomly selected sample sites; and 3) reference sites. We did not use data collected by watershed councils or data collected for TMDL development for status and trend analysis because of data availability limitations and different monitoring objectives. These data sources may provide additional information at a relatively small spatial scale, but do not characterize larger regional conditions.

Monitoring design and analysis information for the three data sets used to assess the Coastal Coho ESU are described separately below. The majority of data used to assess water quality conditions in the ESU comes from the probabilistic monitoring data and the ambient river monitoring. The primary difference between these two monitoring approaches is that the ambient monitoring network design uses a census approach by sampling most of the mainstem rivers within the ESU. This is possible because there are a relatively small number of large rivers to sample. However, because the sites were hand selected rather than randomly selected, the results apply only to the streams sampled and cannot be extrapolated to the overall population of larger rivers in the ESU. The probabilistic design uses a random site survey approach that works well when the number of possible streams to sample is very large, such as the number of 1st through 3rd order streams in the ESU. To describe the condition of all 1st through 3rd order streams in the ESU, without having to sample all of them, a regional random survey of streams provides a statistically unbiased estimate of water quality conditions with a known level of statistical confidence (Herlihy 2000).

Long-term Ambient River Monitoring Sites:

Monitoring Design

The Oregon Department of Environmental Quality (DEQ) maintains a state-wide network of more than 130 ambient water quality monitoring stations of which 31 are located within the Coastal Coho ESU (Figure 3). These sites are located on larger non-wadeable streams (4th order and larger), often near their mouths, and are typically sampled six times per year for long-term water quality status and trends, standard compliance, and problem identification. Sites were selected to represent all major rivers in the state and provide statewide geographical representation. Sites are primarily integrator sites; they reflect the integrated water quality impacts from point and nonpoint source activities as well as the natural geological, hydrological and biological impacts on water quality for the watershed they represent (DEQ 2004).

Analysis Methods

DEQ uses the Oregon Water Quality Index (OWQI) as a tool to describe water chemistry conditions in a consistent manner among streams (Cude 2001). Once index values are calculated, DEQ can describe spatial and temporal trends in water quality at the selected sites.

The OWQI analyzes a defined set of water quality variables and produces a score describing general water quality. The water quality variables included in the OWQI are temperature, dissolved oxygen (percent saturation and concentration) (DO), biochemical oxygen demand (BOD), pH, total solids, ammonia and nitrate nitrogens, total phosphorus, and bacteria (E. coli). OWQI scores range from 10 (worst case) to 100 (ideal water quality).

For this report, OWQI results are calculated on all samples taken from October 1992 through September 2002. These data are analyzed to determine which variables limit general water quality during various seasons. Each site with sufficient data is analyzed for the presence of significantly increasing or decreasing trends. The Seasonal-Kendall test (WQHydro) is used for trend analysis to ensure significant trends are not due to normal seasonal variation. Seasonal averages are calculated for the summer season (June - September) and FWS season (fall, winter, and spring: October - May). The minimum of these seasonal averages is used for ranking purposes.

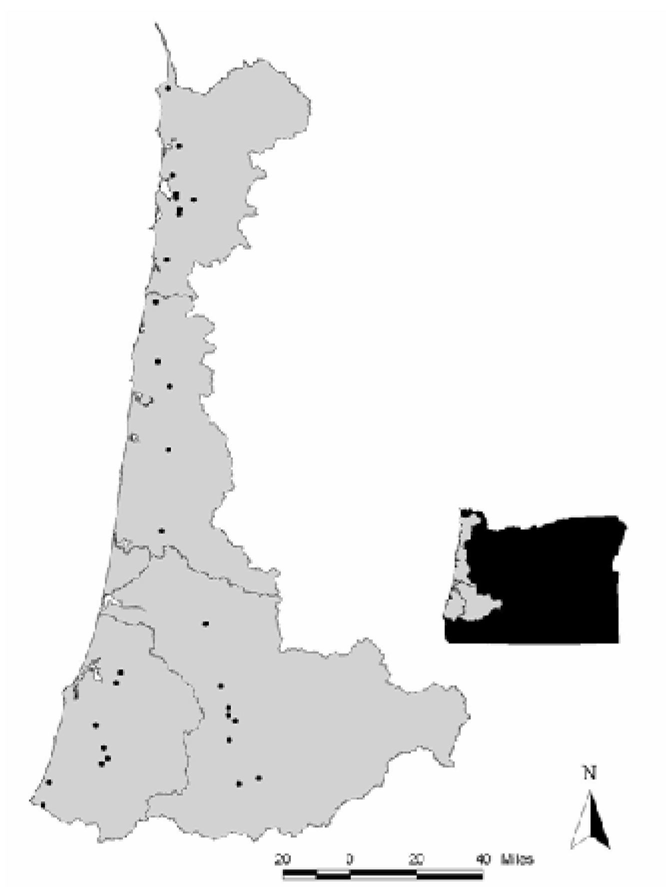
The OWQI was designed to permit comparison of water quality among different stretches of the same river or between different watersheds. The pH and total solids functions within the index help account for geological variability. The OWQI calculation formula, an unweighted harmonic square mean function, accounts for the variability of factors limiting water quality in different watersheds. A classification scheme was derived from application of the OWQI to describe general water quality conditions: OWQI scores that are less than 60 are considered very poor; 60-79 poor; 80-84 fair; 85-89 good; and 90-100 excellent. To account for differences in water quality between low flow summer months (June - September) and higher flow fall, winter, and spring (FWS, October - May), average values for summer and FWS were calculated and compared.

Limitations of Ambient Monitoring Data

Ambient monitoring results are based on grab samples typically collected every other month or six times per year. Because the sites are not randomly selected, the results cannot be extrapolated to all river miles in a monitoring unit or the ESU. For example, it is possible results at an ambient site may not agree with water quality data collected further upstream. This is particularly true for parameters that have diel fluctuations like temperature, dissolved oxygen or pH. Because the ambient data are collected at a single point in time during a 24-hour period, they do not capture the range of conditions over a 24-hour period. Continuously collected data may show different results.

The present OWQI was developed to provide a simple and concise method for expressing the significance of data regularly generated from DEQ's Ambient River Water Quality Monitoring Network. The OWQI only includes conventional pollutant data versus a complete stream quality analysis (i.e. chemical, physical, and biological assessment), and therefore cannot evaluate all health hazards. While the OWQI is an excellent tool for communicating water quality information, analysis of parameter specific data used in the OWQI will enhance understanding.

The Ambient Monitoring Network sites are the best source of water quality data on mainstem segments of the major rivers within the ESU. Due to the long-term sampling history at ambient sites (most have been routinely sampled for decades) they also provide excellent information on trends in water quality on large river sites.



North Coast (9)
- Kilchis River at Alderbrook Road rm 1
- Miami River at Moss Creek Road rm 1.7
- Necanicum River at Riverside Lake Camp rm 5.8
- Nehalem River at Foley Road rm 7.8
- Nestucca River at Cloverdale rm 1.7
- Tillamook River at Bewley Creek Road rm 6.8
- Trask River at HWY 101 rm 4.2
- Wilson River at HWY 101rm 1.8
- Wilson River at HWY 6 rm 8.5

Mid Coast (5)
- Alsea River at Thissell Road rm 17.7
- Salmon River at Otis rm 2.8
- Siletz River 5 miles downstream of Siletz rm 30.9
- Siuslaw River at HWY 126 (Mapleton) rm 20.5
- Yaquina River downstream of Chitwood rm 24.9

Mid-south Coast (8)
- Coquille River at Sturdivant Park Dock rm 24.5
- Floras Creek at HWY 101 rm 4.1
- Middle Fork Coquille River at HWY42 rm 0.2
- Millicoma River at Rooke-Higgins Boat Ramp rm 3.6
- North Fork Coquille River at HWY 42 rm 0.2
- Sixes River at HWY 101 rm 5.5
- South Fork Coos River at Anson Rogers Bridge rm 2.5
- South Fork Coquille River at Broadbent rm 10.0

Umpqua (9)
- Calapooya Creek at Umpqua rm 0.4
- Cow Creek at Mouth (Riddle) rm 0.3
- Elk Creek at Elkton rm 0.2
- North Umpqua River at Garden Valley Road rm 1.8
- South Umpqua River at Days Creek Cutoff Road rm 55.5
- South Umpqua River at HWY 42 (Winston) rm 21.2
- South Umpqua River at Melrose Road rm 5.1
- South Umpqua River at Stewart Park Road rm 10.7
- Umpqua River at Elkton rm 48.4

Figure 3. Ambient Water Quality Monitoring Sites within Coastal Coho ESU.

Probabilistic Monitoring Sites:

Monitoring Design

The Coastal Coho ESU contains a large network of streams comprising many thousands of miles. Most of these stream miles (over 80%) are on small wadeable streams (1^{st} through 3^{rd} order). A practical and effective approach for evaluating such a large resource is to use a probabilistic or random sampling survey design. A probabilistic survey of streams operates in the same manner as public opinion polls used to describe the public's opinion on social issues or winners and losers of political races. A subsample of stream sites is selected at random to represent the population of streams in a region, just as the subsample of individuals in a public opinion poll is selected to represent the voting population as a whole. Regional statistical surveys have been used for many years in forestry and agricultural monitoring programs to determine the condition of forests and agricultural lands, but their use in assessments of aquatic ecosystems is relatively new (Herlihy 2000).

For DEQ's coastal stream survey, 1^{st} through 3^{rd} order streams, within and outside the distribution of coho salmon, were randomly selected across the entire ESU. For this assessment only data from sites within the distribution of coho are analyzed and reported. From 1994 through 2003, a total of 176 unique random sites were sampled across the ESU. Of these 129 were within the coho distribution based on distribution maps from ODFW. A percentage of these sites are also re-sampled every year. As a result the total number of samples for specific parameters is greater than the total number of unique sites. Table 7, summarizes the number of unique random sites and number of samples within the ESU, each monitoring unit, and land use class for those streams within the coho distribution for each parameter. The total number of samples varies between parameters because of missing data, occasional malfunction of field equipment, and/or sampling permit limitations. There are fewer data points for temperature than for other parameters because continuous temperature data collection did not begin until 1998.

Probabilistic data from all years were combined for the analysis of stream conditions in the ESU. This was possible as there was no detectable trend between years in this data set. Data collected at probabilistic sites includes physical habitat, water chemistry and biological assemblages (fish and macroinvertebrates). Sampling protocols followed those of Environmental Monitoring and Assessment Program (EMAP) of the U.S. Environmental Protection Agency (EPA) (Peck et al. 2000).

Analysis Methods

The probabilistic monitoring design allows for an assessment of the status of water quality conditions of wadeable, 1^{st} through 3^{rd} order streams, across the entire Coastal Coho ESU and within subunits (four monitoring units and five land use categories) of the ESU for which sufficient data were collected. Because of the random site selection design, the results from individual sites can be used to estimate the status of all wadeable stream miles within the ESU and subunits with a known level of confidence. To develop regional condition estimates weighting factors are applied to the results from each site based on each site's relative contribution to the entire stream network. For this report, only data from sites within the coho distribution were analyzed. Weighting factors were therefore adjusted according to a streams contribution to the stream network only within the coho distribution. The EPA Office of Research and Development (ORD) developed these techniques for the Environmental Monitoring and Assessment Program (EMAP) (Stevens 1999; Stevens 2004).

The probabilistic site results for each factor for decline have been summarized using Cumulative Distribution Frequency (CDF) graphs and extent bar charts. The CDF graphs show the percentage of stream miles that lie above or below different values for a specific parameter. The extent bar charts show just the percent of stream miles that lie outside specific benchmarks or standards for each parameter. Table 8 shows the benchmarks or standards used to evaluate each factor for decline. The benchmarks are based on existing water quality standards where they exist. For parameters without existing standards, the benchmarks are based on results from references sites (see reference site discussion) or previously established values for aquatic life protection.

Limitations

As with any assessment one must guard against interpreting the data beyond the intended use or design of the study. Therefore, it is important to keep in mind the limitations of the probabilistic data used for this assessment. Limitations to remember when interpreting data from this study include:

- Sample size: The number of data points available for the assessment directly affects the precision of condition estimates based on random site results. DEQ's monitoring study was specifically designed to characterize conditions across the entire Coastal Coho ESU and, as shown in Table 7, the number of data points for different parameters across the whole ESU range from 94 (temperature) to 184 (macroinvertebrates). Dividing this data set into smaller categories (e.g. four monitoring units, and six land uses) reduces the number of data points available to assess conditions at these smaller scales. Fewer data points increases the confidence interval around the condition estimate, and thus makes it more difficult to detect differences in stream conditions between different assessment categories. In a number of cases the number of data points was too small to make condition estimates for a specific monitoring unit or land use category (e.g. Urban streams). For these groups no stream mile estimates are made.

Table 7. Number of Unique Random Sites and Samples by Area and Parameter for wadeable streams within the coho distribution only.

	# Unique Random Sites (1994-2003)	Temperature (1998 to 2003)	Sediment (1994 to 2003)	Dissolved Oxygen (1994 to 2003)	pH (1994-2003)	Nutrients (1994-2003)	Macro-invertebrates (1994-2003)	Fish-Amphibians (1994-2003)
ESU	129	94	183	181	179	180	184	178
North Coast	38	32	57	54	52	53	59	58
Mid Coast	38	26	51	50	50	50	54	50
Mid South Coast	26	17	36	38	38	38	36	37
Umpqua	27	19	39	39	39	39	35	33
Federal Forested	29	20	35	34	34	34	35	36
State Forested	16	13	29	28	27	28	30	28
Private Industrial Forested	44	46	64	61	60	60	61	60
Private Non Industrial Forested	18	8	22	24	24	24	23	22
Agriculture	17	5	25	27	27	27	27	24
Urban	5	2	8	7	7	7	7	8

- Parameter Benchmarks: To evaluate the degree to which factors for decline exceed expected conditions one must define those expectations. For parameters with existing water quality standards, the standard was used as the cut-point or benchmark for comparison. Several parameters, however, do not have established standards, and for those parameters expected conditions were based on the range of conditions found at reference sites. Specifically they were set at the 25th percentile of the distribution of data from reference sites within the ESU.

  Why the 25th percentile? If reference sites were in truly natural condition without any human disturbance, the lowest or highest value from the distribution of reference sites could be an appropriate benchmark for other sites. The reference sites in the ESU, however, were not without human disturbance. In fact most reference sites were affected by more than minimal human disturbance, and the sites represent the "least disturbed" sites that could be found (see Reference Site section below, Table 10). The 25th percentile takes into account that reference conditions were not natural, and was considered the most appropriate level for setting a benchmark with which to evaluate conditions at other sites.

Table 8. DEQ Parameter Benchmarks.

Parameter	Poor	Basis for Break Point
Vertebrate Community Score	< 50	25th percentile of reference sites.
Macroinvertebrate Community Score	< 0.9	25th percentile of reference sites.
Fine Sediment	> 30 %	Aquatic life use protection (Drake 2004).
Water Temperature	> 16 C	Core cold water habitat. Numeric standard
	> 18 C	Salmon and trout rearing and migration habitat. Numeric standard
Dissolved Oxygen Standard	< 8.0 mg/L & <90% saturation	Numeric standard
Total Inorganic Nitrogen	> 0.3 mg/L	25th percentile of reference sites.
Total Phosphorus	>0.03 mg/L	25th percentile of reference sites.
Oregon Water Quality Index	<85	Water Quality for contact recreation and aquatic life use protection (Cude 2001)
Biochemical Oxygen Demand	> 0.8 mg/L	25th percentile of reference sites.
Total Solids	> 66 mg/L	25th percentile of reference sites.
pH	< 6.5 or > 8.5	Numeric standard

- Land use vs. landscape conditions: Part of the evaluation for this report looks at stream conditions across six different land uses. While the results point out some differences between land uses, this analysis should not be used to infer that the differences are due to different land use practices. For Agricultural and Urban land uses the number of sites sampled is too small to make good estimates of overall condition on these lands. Further, landscape conditions (geology, elevation, slope, etc.) also affect stream conditions. Because some land uses are closely associated with certain landscape conditions (e.g. State Forested lands occur predominately in the North Coast Monitoring Unit, which has more erosion resistant geology and steep sloped streams) the current data and analysis cannot clearly separate the affects of landscape conditions from land management practices.

- Trend Detection: One objective of the probabilistic monitoring program is to detect trends or changes in water quality conditions over time. With each year of additional data our ability to detect smaller changes increases. Using the program TRENDS (Gerrodette 1987) we determined what rate of change we will be able to detect with 95% confidence for each water quality parameter over five, ten and 15 year periods (Table 9). For example, in three years (we will then have 10 or more years of data) we will be able to detect a 10% or smaller annual change in seven of the ten water quality parameters.

Table 9. Sensitivity Analysis of water quality and biological condition indices in the Oregon Coast Coho ESU: Based on Data Collected from 1994 to 2003 (1998-2003 for Temperature data).

Variable	Coefficient of Variation of Annual Median Values	Minimum detectable annual rate of change for 3 example study periods[1]			Minimum detectable 10- and 15-year percent change		Median value[2]	Minimum detectable increase or decrease in the median value			
								10-year study		15-year study	
		5 Years	10 Years	15 Years	10-year	15-year		yearly change	10-year change	yearly change	15-year change
Dissolved Oxygen	0.065	11%	3%	1%	23%	18%	7.72	0.23	1.78	0.08	1.39
Dissolved Oxygen Saturation	0.070	12%	3%	1%	25%	19%	76	2.3	19.0	0.8	14.4
pH	0.024	3%	1%	<1%	8%	6%	7	0.07	0.56	<0.07	0.42
Total Solids	0.213	84%	12%	5%	106%	75%	98	12	104	5	74
Total Phosphorus	0.445	>590%	84%	22%	755%	303%	0.053	0.045	0.400	0.012	0.161
Total Inorganic Nitrogen	0.190	61%	10%	5%	89%	64%	0.2	0.020	0.178	0.010	0.128
Macroinvertebrates Community Score	0.109	21%	5%	2%	42%	32%	0.53	0.03	0.22	0.01	0.17
Vertebrate Community Scores	0.083	15%	3%	2%	30%	24%	53	1.6	15.8	1.1	12.7
Temperature	0.060	10%	2%	1%	21%	16%	17.6	0.4	3.7	0.2	2.8
Fine Sediment	0.368	>170%	38%	14%	339%	190%	57	22	195	8	109

[1]Minimum rates of change were determined with a type 1 error of 0.05 (alpha = 0.05) and a type 2 error of 0.8 (beta = 0.8).

Reference Sites:

Monitoring Design

Reference condition is based on the idea that for any given water body (stream, lake, wetland, etc.) there exists a range of conditions unaffected by human activity. Reference condition is best characterized by a set of attributes at undisturbed or minimally disturbed sites characteristic of a water body type in a region. Therefore, within a basin or region, reference condition is described by a group of sites that have relatively unaltered biology, chemistry, and physical habitat. Selecting and sampling reference sites to determine reference condition is an integral part of the monitoring and assessment effort for many environmental assessment programs (Davis et al. 1995; Simon 2003).

All random sites sampled for this study were evaluated for human disturbance and assessed as potential reference sites. The assessment is based on human disturbance factors within the sample reach and watershed, with each site given a class ranking from A to E (Drake 2004). Sites with a ranking of A, B, or C are considered acceptable reference sites. “A” and “B” reference sites can be thought of as representing “minimally disturbed conditions,” and “C” reference sites as representing “least disturbed conditions” (Stoddard et al. in press). Table 10, shows that the majority of reference sites within the coho distribution in the Coastal Coho ESU are “C” sites, and thus the reference site data most accurately reflect least disturbed conditions.

For a more complete discussion of reference site selection and use in the Coastal Coho ESU see Appendix A.

Table 10. Number of unique reference sites per reference site class across monitoring areas and land uses within coho distribution area streams.

Monitoring Area/Land Use	# of "A" Ref Sites	# of "B" Ref Sites	# of "C" Ref Sites	Total
ESU	1		28	29
North Coast			9	9
Mid Coast	1		7	8
Mid-South Coast			5	5
Umpqua			7	7
State Forested			6	6
Federal Forested	1		8	9
Private Industrial Forest			12	12
Private Non-Industrial Forest			1	1
Agriculture			1	1
Urban				0

Analysis Methods

Analysis of reference site results used the same methods described for random site data. Cumulative Distribution Frequency graphs (CDF graphs) and extent graphs were used to summarize reference site data.

Limitations

It is important to remember that most reference sites within the ESU are "C" quality reference sites. This means they represent "least disturbed conditions" rather than minimally disturbed conditions. This may explain why overall conditions within reference sites are not significantly different from conditions at random sites. The number of reference sites within the four smaller monitoring units and land use categories are also too few to characterize reference conditions at these smaller scales. As a result the reference site data best characterize conditions at the ESU scale.

Status & Trends for Water Quality

The ambient monitoring data and the probabilistic monitoring data are assessed separately. The Oregon Water Quality Index has been calculated to evaluate the status and trend of water quality at the ambient river monitoring sites within the overall ESU and within each of the four monitoring areas. Data from the probabilistic sites are summarized for each water quality factor for decline for the entire ESU, the four monitoring areas within the ESU, and across the major land use categories in the ESU: state forested, federal forested, private industrial forest, private non-industrial forest, and agricultural. Conditions in urban land uses could not be evaluated because of the limited number of data points from within that land use.

Ambient Monitoring Data Results:

The status of water chemistry at ambient river monitoring sites is shown in Figures 4 - 8. At the ESU scale 42% of sites show excellent to good water quality and 29% show poor to very poor water quality. Within the four monitoring areas the North Coast shows the best overall conditions (6 sites in excellent or good condition out of 9 sites), and the Mid-South coast the poorest conditions (no excellent condition sites and only 2 out of 8 sites in good condition).

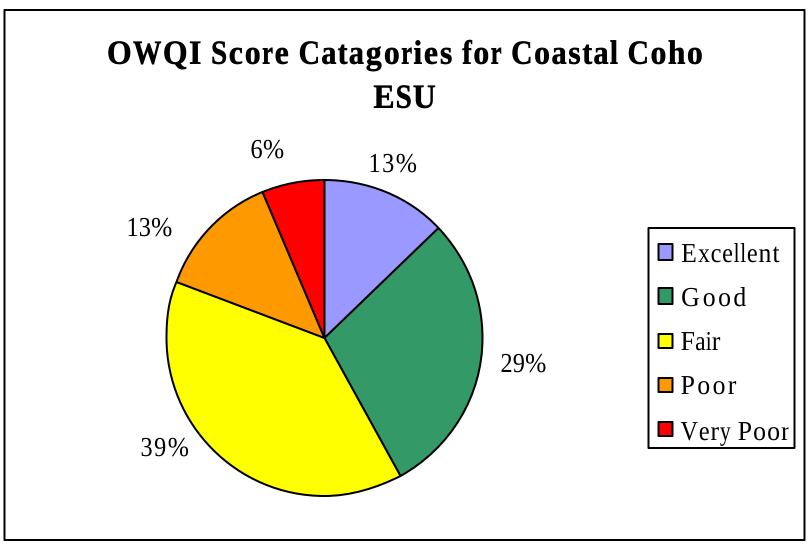


Figure 4. Status for water chemistry at Ambient River Monitoring Sites within Coastal Coho ESU

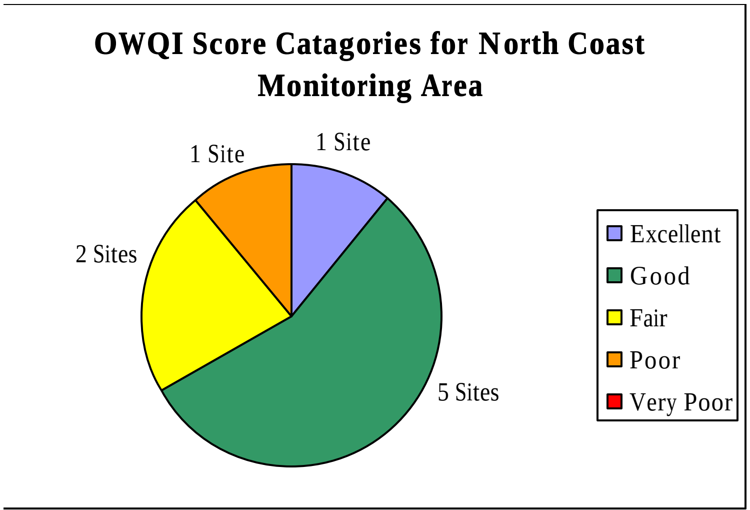


Figure 5. North Coast Monitoring Area

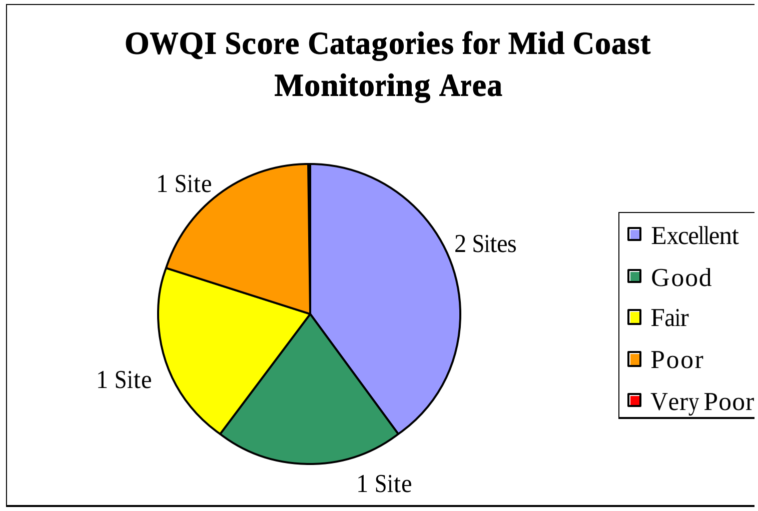


Figure 6. Mid Coast Monitoring Area

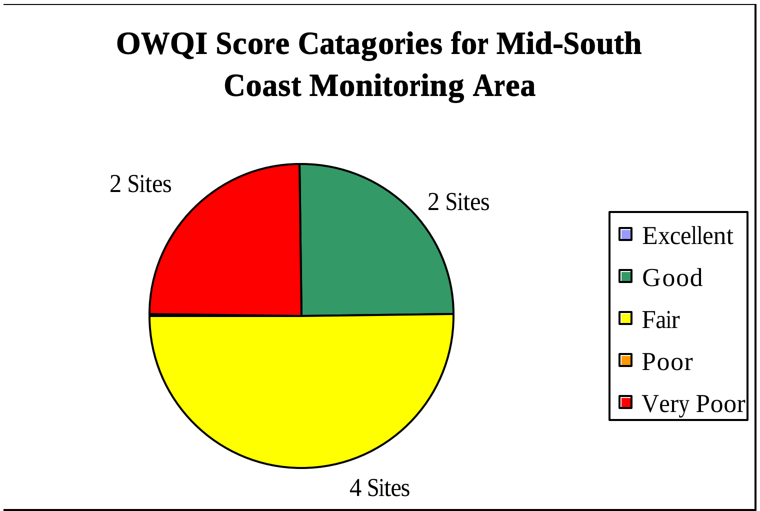


Figure 7. Mid-South Coast Monitoring Area

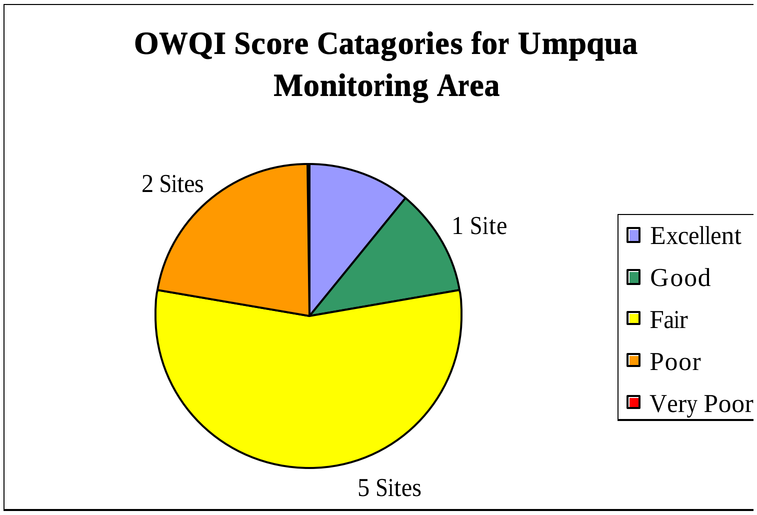


Figure8. Umpqua Monitoring Area

Trends in water quality at the ambient sites are shown in Table 11. No sites showed a declining trend in water quality for the ten-year period between October 1992 and September 2002. The area with the most improving trends was the North Coast where 66% of the sites (6 out of 9) had a significant improvement in OWQI scores. The Umpqua basin, with one out of 9 sites (11%) showing an improving trend, had the lowest number of improving sites.

Table 11. Water Quality trends at Ambient Monitoring Sites from October 1992 to September 2002 within ESU and four Coastal Monitoring Areas.

Water Quality Trends	ESU	North Coast	Mid Coast	Mid-South Coast	Umpqua
Percentage of sites with improving water quality	39%	66%	20%	50%	11%
Percentage of sites with declining water quality	0%	0%	0%	0%	0%
Percentage of sites with no trend in water quality	61%	34%	80%	50%	89%

In addition to evaluating status and trends of water quality conditions, it is also important to determine what water quality parameters pose the greatest threat or risk to stream health. In this context water quality parameters may be thought of as potential stressors to water quality.

DEQ analyzed parameter specific data to determine what was driving the OWQI scores. The mean subindex value for each parameter (“stressor”) in the OWQI was calculated for October 1992 – September 2002. Mean subindex values (Temperature, Dissolved Oxygen, BOD, pH, Total Solids, Nitrogen, Total Phosphates, and Bacteria) were ranked in order from lowest to highest for each site. Ranked point values (1-8) were given to each parameter at each site relative to its contribution to the OWQI score.

The parameter specific analysis allowed DEQ to evaluate which parameter posed the highest risk to water quality within the ESU at ambient monitoring locations. The highest ranked parameter for each site was considered the primary risk factor. The primary risk factor to water quality throughout the ESU is shown in Figure 9. Out of the total 31 sites, the primary risk factor affecting the OWQI was as follows: Total Solids (58% of sites), Nitrogen (32% of sites), BOD (6% of sites), and Bacteria (3% of sites) (Figure 8).

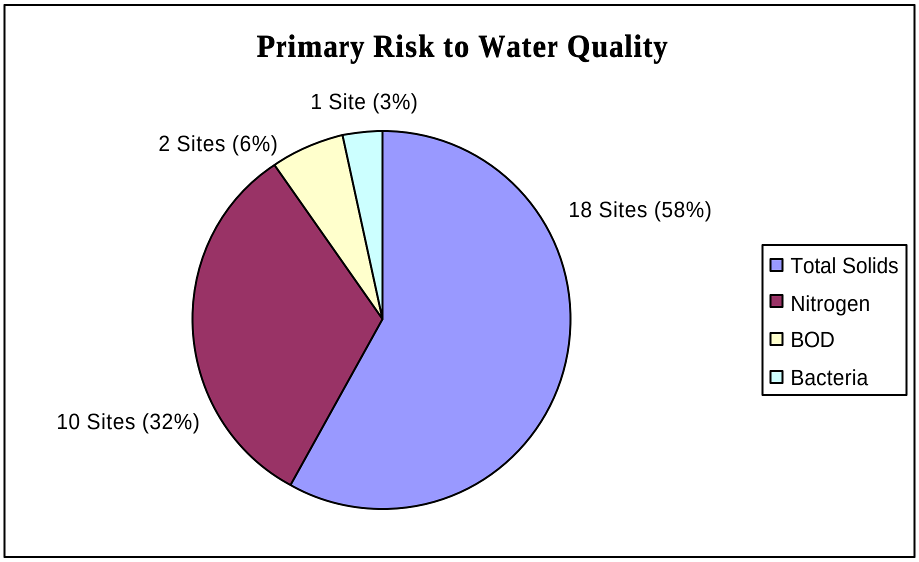


Figure 9. Primary Risk Factors to Water Quality at Ambient River Sites.

We also compiled all site relative stressor rankings for each parameter at each site in the ESU and determined the mean rank score for each stressor across all sites. The relative rank of stressors across all 31 ambient stream sites in large rivers is displayed in Table 12. Total Solids is the most important stressor and pH is the least important stressor at large river ambient sites.

Table 12. Relative Rank of Stressors in Large Rivers (Ambient Sites)

Stressor	Relative Rank
Total Solids	Most Important
BOD	↓
Nitrogen	
Phosphorus	
Bacteria	
Temperature	
DO	
pH	Least Important

Probabilistic Data Results:

Results from the probabilistic or random site surveys are summarized below for each of the parameters listed as a factor for decline. Only data from sites within the distribution of coho have been included in this analysis. Because of the random sampling design results reflect the percent of all wadeable stream miles within the Coho distribution for each parameter. Results are calculated for the entire Coastal Coho ESU, for each of the four monitoring areas, and for different land use classes within the ESU. To characterize the nature and extent of each parameter the results have been summarized as follows:

1. A cumulative distribution frequency graph (CDF graph) that shows the distribution of conditions for the parameter as a percent of stream miles for the whole ESU and each sub-classification. **See Appendix B for all CDF graphs.**

2. The extent (percent of stream miles) that exceed specific benchmarks or standards. The benchmarks used for each parameter are shown in Table 8. Water quality standards are used as the benchmark for parameters with existing numeric water quality standards. For parameters without numeric standards either the 25th percentile of the reference site distribution was used as the benchmark, or previously established break points protective of aquatic life.

3. A "relative risk" assessment that evaluates both the extent of a parameter's condition and its potential risk to affect fish or macroinvertebrate assemblages (Lachin 2000).

<u>Water Temperature</u>

Temperature is an important factor in species distribution in aquatic habitats. It may affect either physiologic processes (Coutant 1987) and/or species interactions (Taniguchi et al. 1998). As a result animals often compete for and partition habitats along temperature gradients. In this way temperature can directly affect the fitness and distribution of species within a stream or region.

Water temperature was collected at each random site using a continuous temperature recording thermister following DEQ protocol (DEQ 2004). Thermisters were typically placed in streams in May or June and retrieved in September or October. The 7-day maximum average temperature was calculated for each site and compared to the temperature standard for that site (16 or 18 degrees Centigrade depending on ODFW rearing classification).

Figures 1 - 2 in Appendix B show the cumulative distribution frequencies for temperature for the monitoring areas and land use categories, respectively. Figure 10 shows the percent of stream miles exceeding the temperature standard for each monitoring area and land use. Fifty-four percent of stream miles within the coho distribution in the ESU exceeded the temperature standard. However, 61% of reference sites from within the coho distribution area also exceeded the standard. This suggests that both natural and anthropogenic factors contribute to elevated stream temperatures.

There were no significant differences in stream miles above the standard between monitoring areas or land uses. The North Coast monitoring area had the fewest stream miles above the standard (31%), and the Umpqua had the most miles above the standard (77%). Because of low numbers of samples, the miles of streams above the standard could only be estimated for two land use classes: Federal Forested and Private Industrial Forest. Seventy-seven percent of stream miles on Federal Forested lands exceeded the standard, and 43% of stream miles exceeded the standard on Private Industrial Forest lands, however, these estimates were not significantly different.

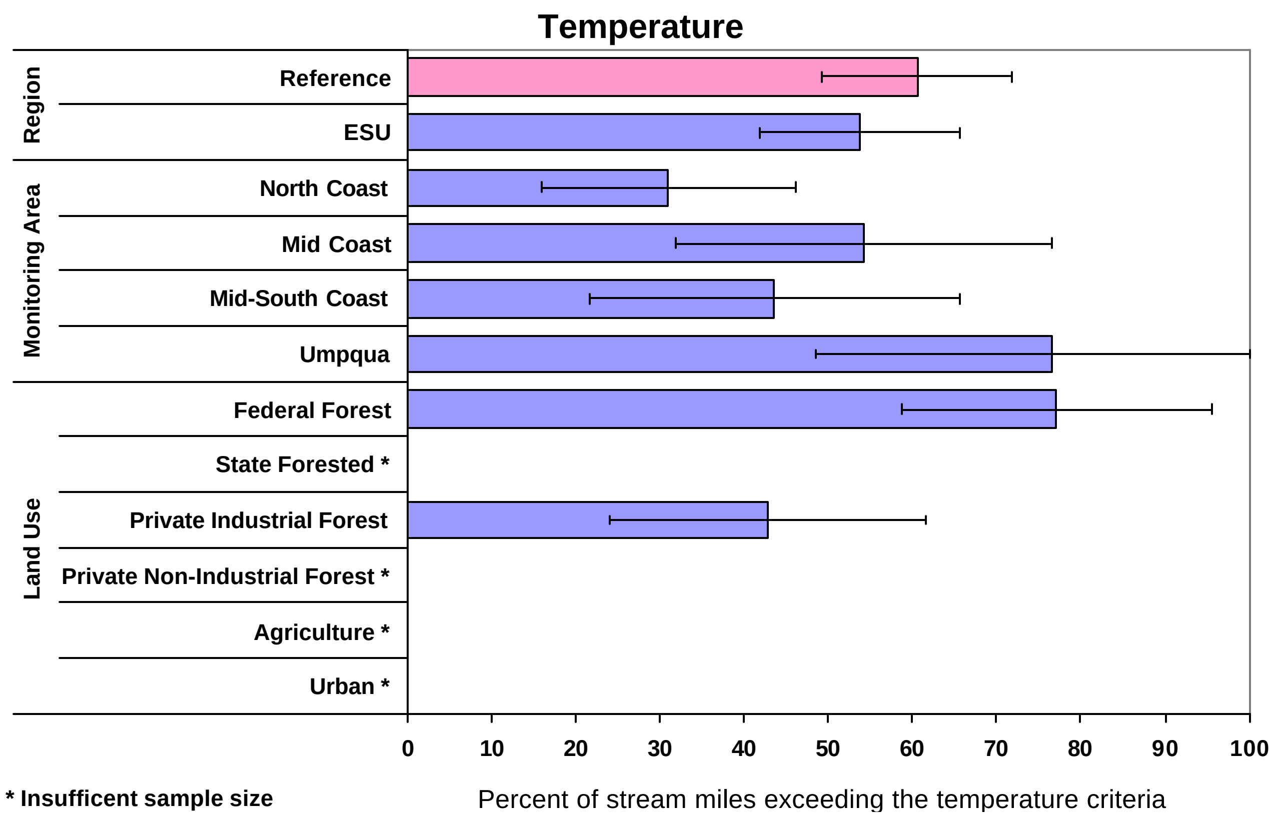


Figure 10. Percent of stream miles exceeding temperature criteria for Reference Sites, ESU, Monitoring Unit and Land Uses. (Error bars represent the 95% confidence intervals)

Dissolved Oxygen

Dissolved oxygen is absolutely essential to coho salmon and other aquatic animals that rely on aerobic respiration for life. A number of factors are important in determining the amount of oxygen in water. Temperature is a critical factor in determining oxygen levels, because oxygen solubility in water decreases as water temperature increases. Oxygen is about 19% less soluble in 20°C water than in 10°C water (Hutchinson, 1957). Dissolved oxygen levels are also influenced by barometric pressure that varies with elevation and weather. The amount of oxygen water will hold decreases at higher elevations and as barometric pressure decreases. Another factor that influences dissolved oxygen is the biological activity of the water body. Photosynthesis by algae or macrophytes releases oxygen into the water, some times leading to super saturation levels over 100%. Likewise, aerobic respiration can deplete dissolved oxygen to very low levels when high biochemical oxygen demand exists. Dissolved oxygen can vary daily and annually as a result of differing solar energy, temperature, photosynthesis, and respiration, especially in slow moving streams with high levels of biological activity. Water turbulence can restore dissolved oxygen to atmospheric equilibrium through aeration.

We measured dissolved oxygen using a Winkler titration conducted in the field in a single sample collected from the center of the stream channel typically at mid morning at the start of a given stream survey. The Oregon dissolved oxygen standard applicable in the water column of coho distribution streams is 8.0 mg/liter. If conditions of barometric pressure, altitude and temperature preclude to achievement of 8.0 mg/liter then 90% saturation applies (OAR 340-41-006).

All but 9.8% of the stream miles achieved the standard (Figure 11). Every one of the reference streams met the standard. No monitoring area or land use had levels of standard non-attainment significantly different from the ESU. Among the monitoring areas the Mid-South and North Coasts had the best compliance, with all but 3.4% and 6.4% respectively, attaining the standard. The Umpqua Monitoring Area had the highest level with 14.5% not attaining the standard. The land use class with the highest level of standard non-attainment was Private Non-Industrial Forest with 31%, followed by Agriculture at 13.1%. Standard non-attainment for Private Industrial Forest was 4.6% and 1.4% for Federal Forest. All streams on State Forested lands met the standard.

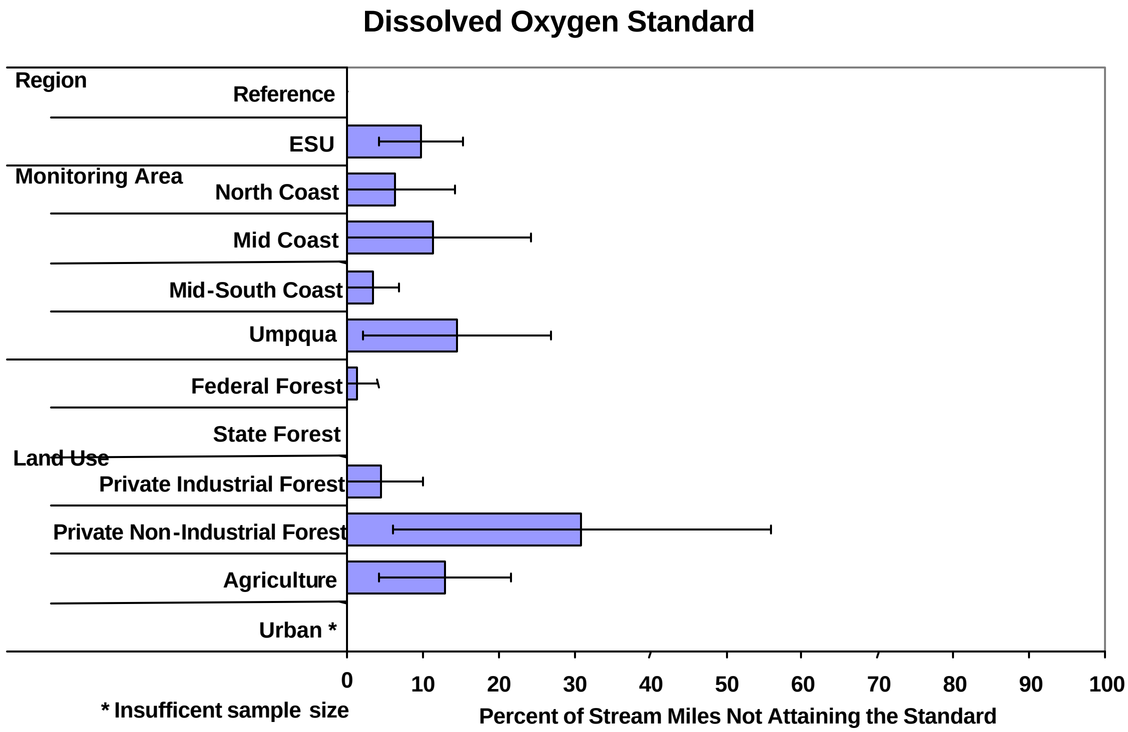


Figure 11. Percent of stream miles within coho distribution not attaining the dissolved oxygen water column standard of 8.0 mg/L or 90% saturation if barometric pressure, altitude, and temperature preclude attaining this concentration. (Error bars represent the 95% confidence interval)

pH

pH is an important and frequently measured water quality parameter. It is critical for the growth and survival of fish and other aquatic life. It affects the toxicity of pollutants such as heavy metals and ammonia and, like water temperature and dissolved oxygen, pH can vary daily and seasonally. Our pH values were measured using a pH meter with a glass electrode in a water sample typically collected mid morning.

pH has a scale from 0 to 14 based on the activity of hydrogen ions. Waters with high hydrogen ion activity will have low pH values (less than 7) and will be acidic. Waters with a low hydrogen ion activity will have a high pH (greater than 7) and be basic. Water with a pH of 7 is neutral. Natural, unpolluted waters typically have pH in the range of 6.5 to 8.5, the Oregon water quality standard for pH. pH values above and below this range are adverse to salmonid survival.

One of the factors that could lead to pH values above or below this range would be excessive algal growth. Algal photosynthesis and respiration in areas with dense algal growth would increase pH during the day through the absorption of carbon dioxide and then decrease pH at night through carbon dioxide excretion. Excessive algal growth could be due to high nutrient loading that fertilizes algal growth; wide, shallow, and poorly shaded stream channels due to excessive sedimentation, and riparian habitat disturbance that allows for increased solar energy used in photosynthesis to reach the stream. Diel swings in pH can be very stressful to sensitive aquatic species such as salmonids. We typically measured pH in a single water sample collected mid morning due to sampling constraints. Mid afternoon or early morning (before sunrise) sampling times would better determine if pH problems existed.

Figure 12, shows the extent of stream miles that exceeded the pH standard. Only one random site in the coho region of the ESU exceeded the pH standard, and no pH standard violations were observed for reference streams.

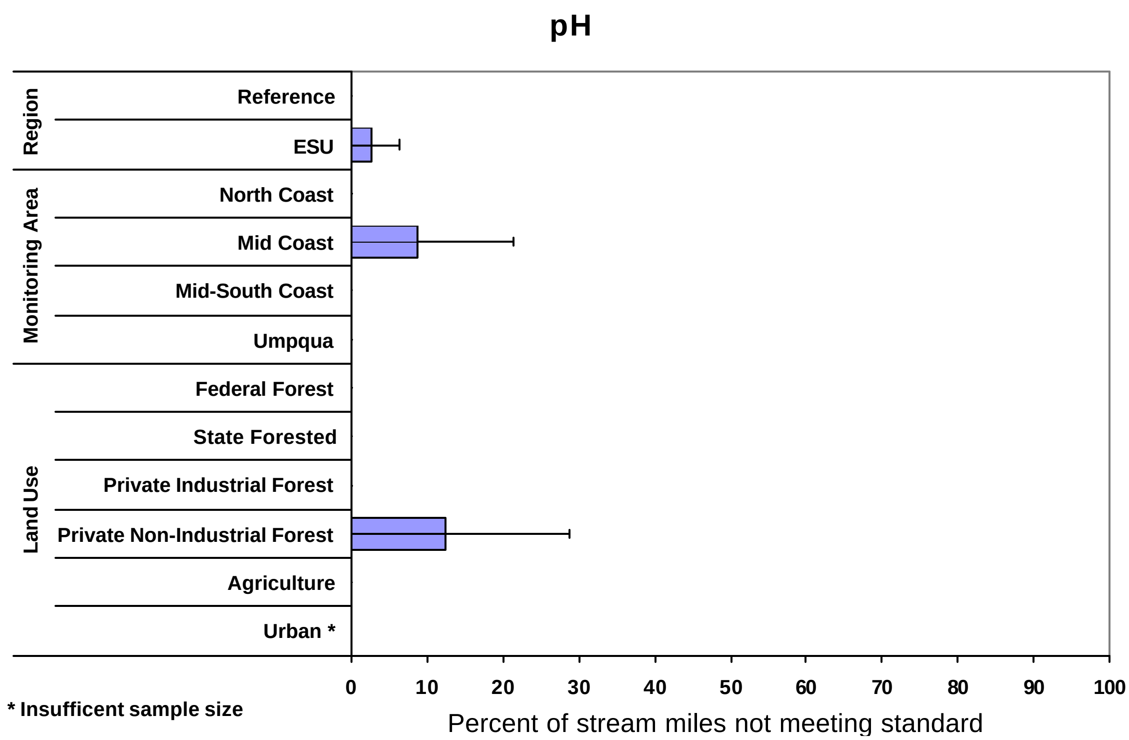


Figure 12. Percent of stream miles within coho distribution not meeting the pH standard. (Error bars represent the 95% confidence interval)

Stream Fertility (Nutrients)

Stream fertility depends on a complex combination of nutrients, some of which enter streams via groundwater and surface runoff through local soils. Runoff from human applied fertilizers or animal or human waste may also contribute significant amounts of nutrients to streams. Other sources of nutrients come from the decomposition of terrestrial plants, primarily leaves and debris, and animals, mostly from fish carcasses. The primary effect of increasing nutrients is an increase in algal and aquatic plant growth.

Algae, like other plants, require a wide range of substances for normal growth. Typically, most of these substances are available in aquatic system in excess of what plants require so that they usually do not restrict or stimulate growth. However, nitrogen and phosphorus are common exceptions as they are frequently present in limited supply relative to the nutritional requirements of plants. Since algae feed aquatic insects that become food for young fish, the amounts of nitrogen and phosphorus nutrients present can significantly control the overall fertility of a water body and affect salmonid growth and survival. Too little nitrogen and phosphorus may mean a reduced food supply for juvenile salmonids. Too much may lead to excess algal growth, which can cause pH and dissolved oxygen levels unhealthy for sensitive species such as salmonids.

Human activity in a watershed typically increases nutrients. Excess nitrogen and phosphorus loading to streams can result from agricultural and urban lands due to run off contaminated with fertilizers, erosion or waste water discharge. Nutrient inputs may also decrease by a reduction in marine derived nutrients from reduced salmon carcasses.

Nitrogen and phosphorus can exist in many forms and some forms are more available to algae for growth than others. The form of nitrogen reported here is total inorganic nitrogen. It is made up of ammonia, nitrate and nitrite forms of nitrogen that are dissolved in the water and can be absorbed by algae for growth. It does not include particulate or organic nitrogen, which are less available for growth. The phosphorus reported here is in the form of total phosphate, which may include some relatively unavailable forms of phosphorus.

The percent of stream miles with nitrogen and phosphorus concentrations above reference benchmarks (25^{th} percentile of reference sites) are given in Figures 13 and 14, respectively. Appendix B, Figures 7 & 8, show the complete range of values plotted in CDF graphs.

More than three quarters of ESU streams met the nitrogen benchmark (0.3 mg/l). None of the monitoring units or land uses was statistically different from reference streams for the extent of stream miles over the nitrogen benchmark. The Umpqua and Private Non-Industrial Forest streams had the lowest nitrogen levels with only 5 to 7% of the streams exceeding the benchmark. These stream groups had significantly few stream miles over the benchmark than the region as a whole. Agriculture had a significantly greater number of high nitrogen streams compared to the region as a whole with about 40% of the streams miles over the nitrogen benchmark.

Regionally, phosphorus was one of the most extensive stressors, with more than 40% of the stream miles over the benchmark (0.03 mg/l), suggesting a high background level of phosphorus. For monitoring areas and land uses only streams on State Forested land was significantly different than the least human impaired reference sites. State Forested streams were significantly lower in phosphorus than reference streams and the ESU as a whole, with less than 3% of stream miles above the benchmark. Agriculture had the greatest percent of high phosphorus streams with almost 70% exceeding the benchmark, although this was not statistically different from reference streams or from the region as a whole. Umpqua and Private Industrial Forest streams were also high with between 50 to 60% above the benchmark.

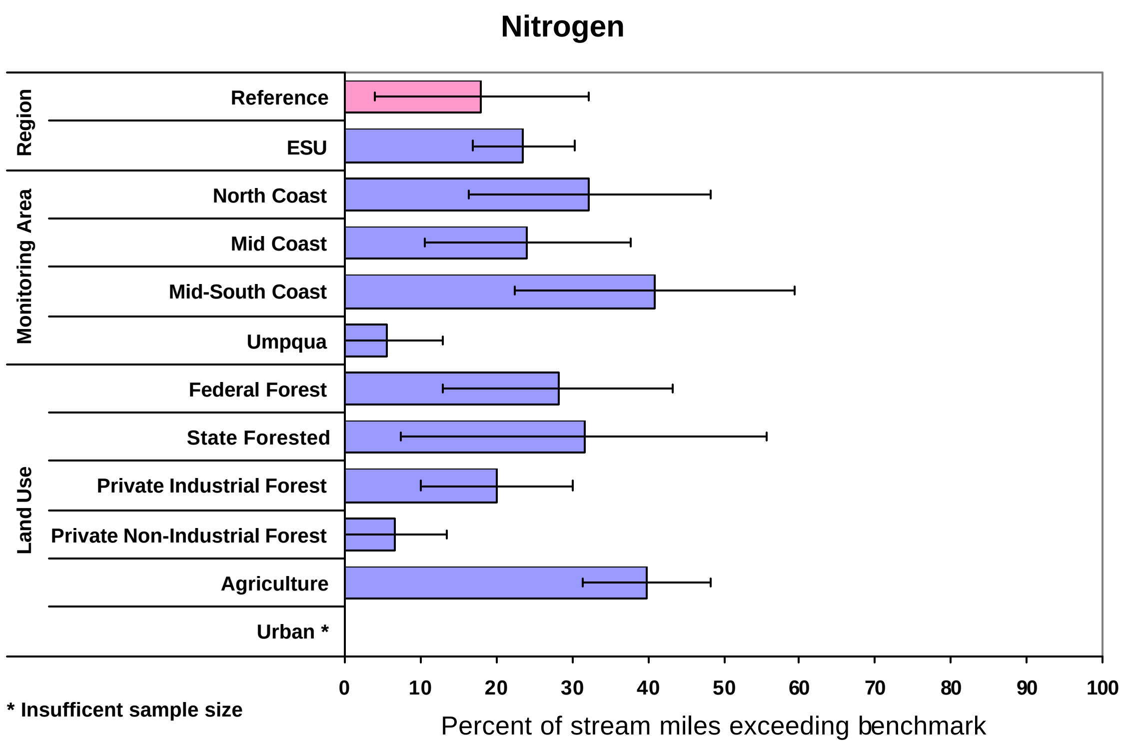


Figure 13. Percent of stream miles within coho distribution exceeding the nitrogen benchmark. (Error bars represent the 95% confidence interval)

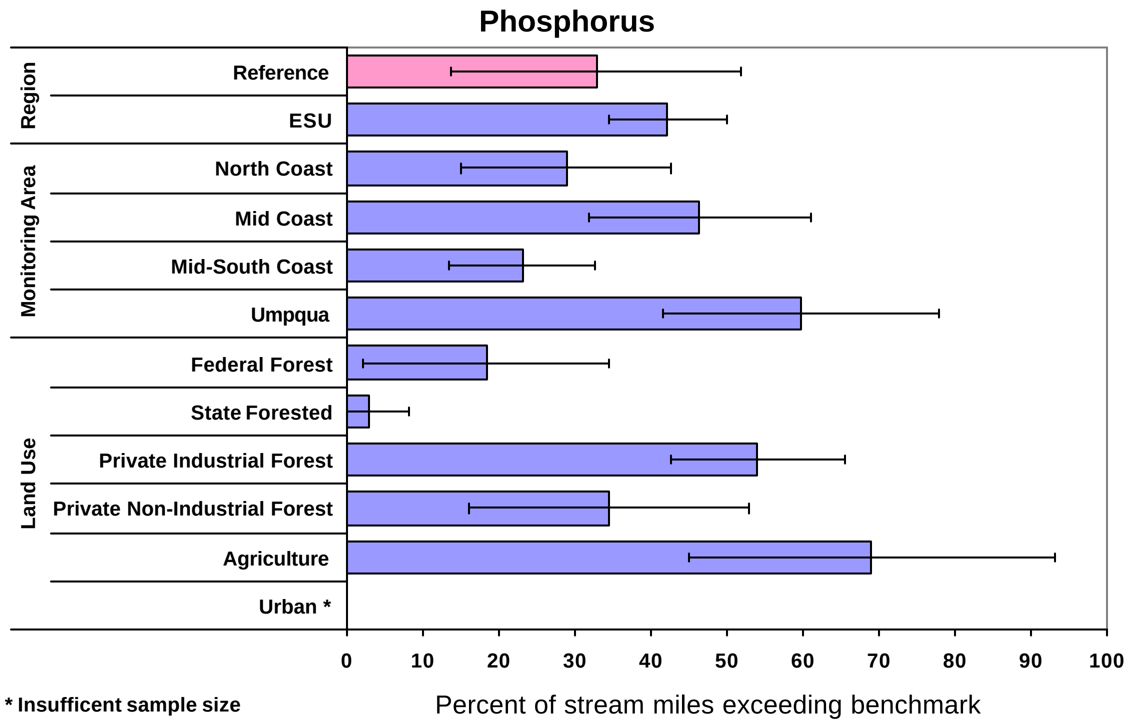


Figure 14. Percent of stream miles within coho distribution exceeding the phosphorus benchmark. (Error bars represent the 95% confidence interval)

Sediment

The detrimental effects of excess stream sediment on juvenile salmon survival and growth are well documented (Suttle et al. 2004; Waters 1995; Bjornn et al. 1974). Fine sediments can clog the interstitial spaces between coarse gravels and cobbles and inhibit the flow of fresh, oxygenated water over redds thereby reducing survival. In addition, excess sediment deposition on redds can physically impede emerging fry. During critical overwintering periods, suspended sediment may reduce foraging efficiency and at critical levels, damage gill structures. Therefore, human activities such as road building (Beschta 1978), logging (Beschta 1978; Hall, J.D. and R.L. Lantz 1969), agriculture (USEPA 1990), grazing (Platts 1991) and mining (Waters 1995), which are demonstrated to increased fine sediment deposition, are of concern.

In order to evaluate substrate conditions at our sites, we used a modified Wolmann pebble count taken at five points across the stream channel on 21 transects along a forty channel width section of stream. Substrate was categorized into one of ten size classifications. In this report, the fine sediment (FN) (<0.06mm) and sand (SA) (>0.06to 2mm) categories were combined to calculate the relative percentage fines and sand as a proportion of the total substrate.

In addition, we measured the Total Solids (TS) (mg/L) concentration in the water column as an indication of the suspend component of sediment. Total Solids represents the suspended and dissolved solids measured from a water sample collected at the stream site.

Fine Sediment (FN+SA):

Fine sediment showed greater variation across land use classifications than regionally (Appendix B, Figures 9 & 10). Our data do not show a significant difference between the extent of fine sediment found at random and reference streams at the ESU or Monitoring Unit scales (Figure 15) although, reference streams did show the lowest extent (26%) above the sediment benchmark (30% fine sediment). The Umpqua had the highest extent of stream miles exceeding the benchmark for fine sediment (47%) followed closely by the Mid-Coast (44%). The North Coast showed the lowest number of stream miles above the benchmark (30%) of the four monitoring units.

Agricultural streams had significantly more stream miles with high fine sediment than reference streams and the most stream miles above the benchmark of any classification (63%). State Forested (15%) and Federal Forested (16%) streams had the lowest percentage of stream miles above the benchmark.

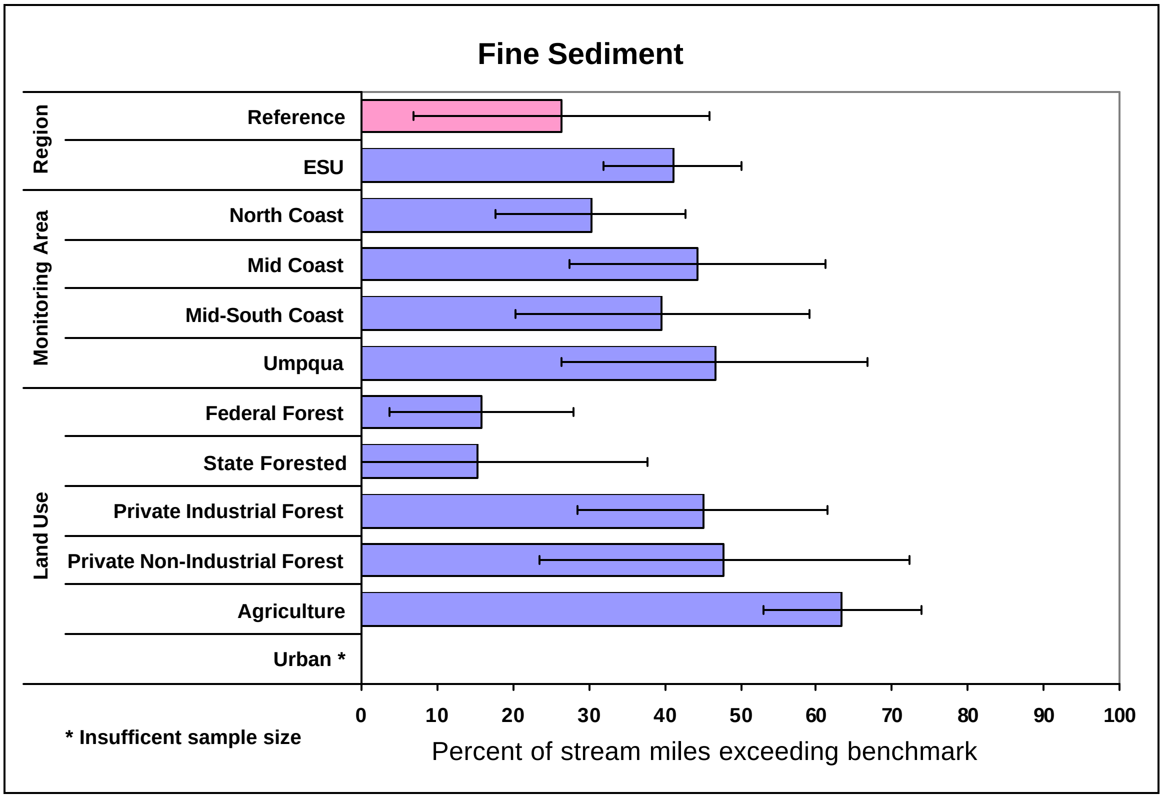


Figure 15. The percentage of stream miles that exceeded the benchmark for fine sediment (FN+SA) across Reference streams, the ESU and the four monitoring units and across six land use categories. (Error bars represent the 95% confidence interval)

Total Solids (TS):

The Umpqua Monitoring Unit had significantly more stream miles with high Total Solids (71%) than Reference streams (24%), the ESU (47%), the North Coast Monitoring Unit (33%) or the Mid-Coast Monitoring Unit (33%) (Figure 16). No other significant distinction can be made across the regions, even though reference streams had fewer miles above the benchmark than the five geographic monitoring areas.

Agricultural streams had significantly more stream miles above the benchmark for Total Solids (73%) than reference streams (24%), State Forested streams (21%), Federal Forested streams (25%), Private Industrial Forested streams (49%) or Private Non-Industrial Forested streams (21%). No other distinctions between land use classifications can be made. Overall State Forested streams had the fewest stream miles with high Total Solids for any grouping.

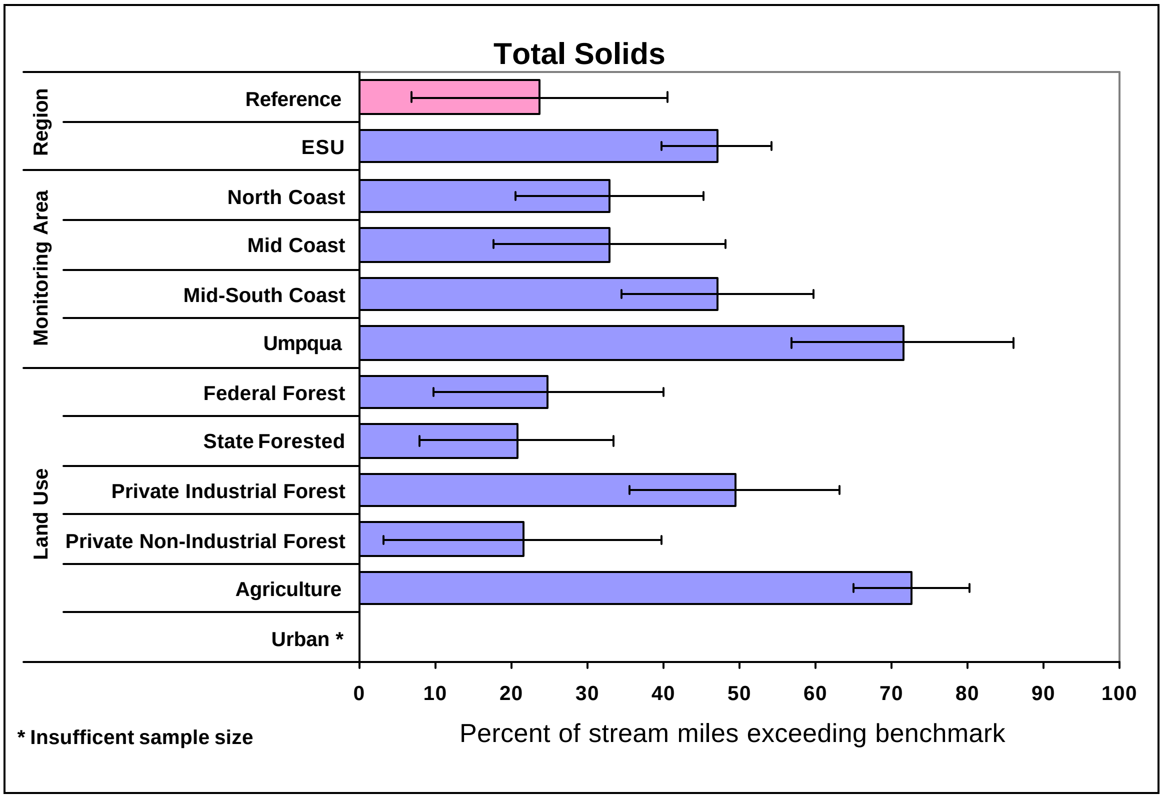


Figure 16. The percentage of stream miles that exceeded the benchmark for Total Solid (TS) across Reference streams, the ESU and the four monitoring units and across six land use categories. (Error bars represent the 95% confidence interval)

Biological Conditions

Both aquatic vertebrate (fish & amphibian) and macroinvertebrate assemblages were collected at each random site following DEQ protocol (DEQ 2004). An index of biotic condition based on species diversity and structure has been developed for each assemblage. For the fish-amphibian assemblage a multi-metric index (vertebrate IBI) was used (Hughes et al. 2004). For macroinvertebrates a multivariate model was developed to assess assemblage condition (Hawkins et al. 2000). A more detailed description of each index is provided in the following aquatic vertebrate and macroinvertebrate sections.

One of the main advantages of assessing biological communities is that the diversity and structure of the assemblage present on the day of sampling indicates both current and past stream conditions for a variety of parameters. For example, a toxic chemical that enters a stream may be present in the water for a short time (one or two days). The effect on the aquatic species, however, could potentially be observed weeks or even months later by detecting changes in the biological assemblages from what was expected. Likewise, relatively small changes within a watershed for a variety of parameters over time may result in measurable changes in biological assemblages. In this way biological data represent an integrated assessment of habitat and water chemistry conditions over a period of months rather than a brief snap shot of conditions on the day of sampling.

The condition of biological assemblages (fish & macroinvertebrates) may also directly affect instream salmonid condition. The introduction of alien fish species for example will lower the vertebrate IBI score and can have a direct competitive or predator affect on juvenile coho. Likewise, macroinvertebrates are a principle food for juvenile salmonids, so shifts in their assemblages can affect salmonid nutritional status. When compared to actual juvenile coho abundance data, the fish IBI and macroinvertebrate index scores in the ESU were moderately correlated with coho (Pearson Correlation Coefficient = 0.4 & 0.2, respectively).

The lack of a stronger correlation is not surprising, however, since coho abundance is affected by factors outside the local freshwater environment like ocean conditions and fisheries management. In addition the macroinvertebrate index does not assess productivity (abundance or biomass of invertebrates), and therefore, a reduction in the invertebrate index score may not mean a reduction in food for coho has occurred. Measuring productivity, however, is considerably more variable and expensive, and beyond the scope of this monitoring effort.

Because these biological indices are largely unaffected by conditions outside the local freshwater stream environment, unlike coho populations, we believe they provide a direct indication of current freshwater conditions and, over time, can indicate the effectiveness of management actions. In addition, the stressors that affect fish and macroinvertebrate diversity and structure – reduced habitat complexity, high temperature, fine sediment and low dissolved oxygen – also affect coho. Therefore, improving trends in the fish and macroinvertebrate biological indices would also indicate conditions for coho have improved.

Aquatic Vertebrate Assemblage:

The aquatic vertebrate community condition was assessed across the ESU, the four monitoring units and across land use types. For this assessment, we used an index created for coldwater streams in western Oregon and Washington (Hughes et al. 2004). The index is comprised of eight metrics that reflect assemblage composition, structure and function, seasonal variance, and low natural gradient response coupled with high anthropogenic disturbance response. The final IBI score is the average of the eight metric scores: 1) percent alien species, 2) percent coolwater individuals, 3) percent anadramous individuals, 4) percent coldwater species, 5) number of tolerant individuals, 6) number of native coldwater species, 7) number of native coldwater individuals and 8) number of size classes multiplied by 100.

Across the four monitoring units, IBI scores ranged from a low score of 21 to a high score of 93 (Appendix B, Figures 11 & 12). None of the Monitoring Units were statistically different from the reference site population (Figure 17). Overall, the North

Coast had significantly fewer stream miles not meeting the benchmark for the IBI than the ESU, the Mid Coast Unit and the Umpqua. The Umpqua had the most stream miles (40%) not meeting the IBI benchmark.

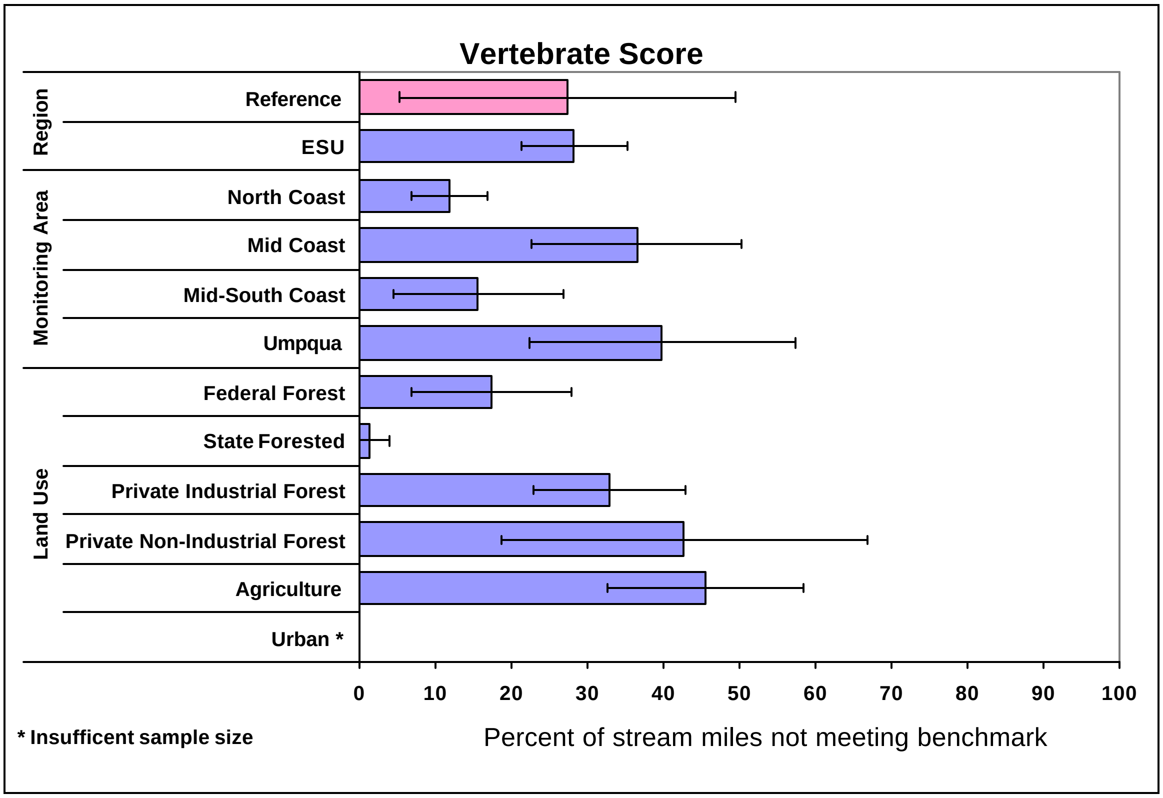


Figure 17. The percentage stream miles not meeting the benchmark for the Index of Vertebrate Integrity (IBI) across Reference streams, the ESU and the four monitoring units and across six land use categories. (Error bars represent the 95% confidence interval)

Within the land use categories, State Forested land had significantly fewer stream miles not meeting the benchmark than any other land use including the reference population. None of the other land use categories was significantly different from the reference population or different from each other. Agriculture had the most stream miles (46%) not meeting the benchmark for the IBI.

Non-Native Fish and Amphibians:

The detrimental impacts of exotic fish species introductions on native taxa are well established (Allen, 1992). However, the complex interactions between introduced taxa and native taxa make it difficult to tease apart direct effects such as predation, competition and hybridization, and other concurrent effects such as habitat alterations and changes in hydrology. It is clear that the presence of exotic species is a good indicator of declines in native taxa (Ross, 1991). This makes exotic species a useful indicator of impairment, particularly as they relate to native fauna.

Across the ESU, we found five distinct exotic species at six locations (Table 13). This represents exotic species occurring at approximately four percent of the stream miles in the region (Figure 18). The Umpqua monitoring area had the most stream miles with exotic species (7.5%) followed by the Mid-south Coast with (6.0 %). Across the land use categories, Agriculture had 11.9% of the stream miles with exotic taxa followed by State Forested land with 3.0 % of the stream miles. None of the monitoring areas or land use categories was statistically different from reference.

Table 13. Locations and exotic species found across the ESU coho distribution area.

Monitoring Unit	Location	Common Name	Genus	Species
NOCO	Middle Fork of the North Fork Trask River at RM 3.0	Catfish	NA	NA
MICO	South Fork Siuslaw River at RM 2.3	Bullfrog	*Rana*	*catesbeiana*
MISO	Fishtrap Creek at RM 1.4	Brown bullhead	*Ictalurus*	*nebulosus*
MISO	Fishtrap Creek at RM 1.4	Bluegill	*Lepomis*	*macrochirus*
UMPQ	Cabin Creek at RM 5.6	Pumpkinseed	*Lepomis*	*gibbosus*
UMPQ	Elk Creek at RM 34.2	Pumpkinseed	*Lepomis*	*gibbosus*
UMPQ	Ollala Creek at RM 11.6	Bluegill	*Lepomis*	*macrochirus*
UMPQ	Ollala Creek at RM 11.6	Bullfrog	*Rana*	*catesbeiana*

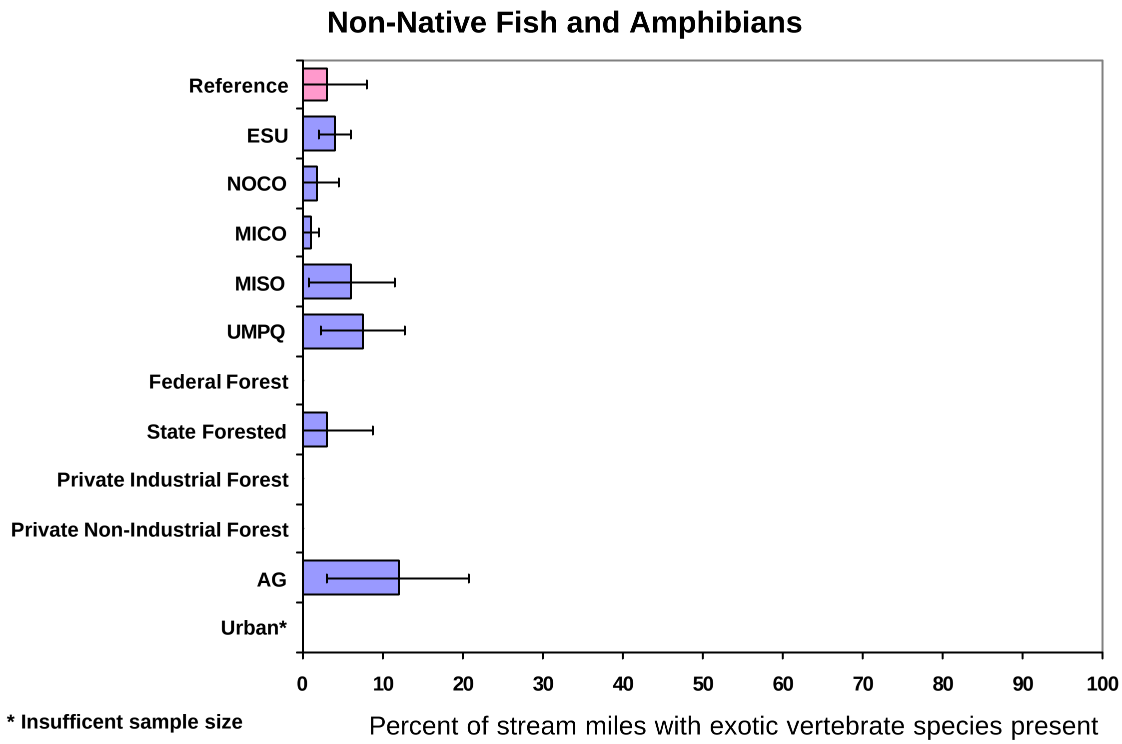


Figure 18. The percentage of stream miles with exotic fish or amphibian taxa present across reference streams, the ESU, four monitoring units, and six land use categories. The error bars represent the 95% confidence interval.

Macroinvertebrate Assemblage:

The macroinvertebrate assemblage includes all aquatic invertebrates larger than 0.5 mm. The dominant invertebrates in minimally altered streams tend to be species of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera). These three groups are referred to as the "EPT" taxa. Many other groups of invertebrate taxa are also present in healthy streams, and the number (diversity) and type (structure) of species present depends on the habitat and water quality present in the stream sampled.

To assess changes in the macroinvertebrate assemblage a multivariate model known as the **R**iver **I**nvertebrate **P**rediction **a**nd **C**lassification **S**ystem, or RIVPACS, has been developed for streams in Oregon including the Coastal Coho ESU (Hawkins et al. 2000). This approach uses macroinvertebrate and habitat data from reference sites sampled at a range of streams across the region to develop a predicted set of "expected" taxa for each site being assessed. The actual or "observed" set of invertebrate taxa at a site is compared to the expected set, and the ratio of the observed to expected taxa is calculated. The observed over expected (O/E) score may range from 0 to 1.0, with 0 indicating the observed taxa have no similarity to the expected taxa, and 1.0 indicating a perfect match between observed and expected taxa. Sites with O/E scores less than 0.9 are in the lower

25th percentile of reference site scores and are considered to have stressed or impaired macroinvertebrate assemblages (see Table 8).

CDF graphs of macroinvertebrate O/E scores for monitoring areas and land uses are shown in Appendix B, Figures 13 & 14, respectively. The percent of stream miles with low O/E scores (below the benchmark) for monitoring areas and land uses is shown in Figure 19. The results show no significant differences between the monitoring areas and the reference sites from within the coho distribution. The mid-south coast had the lowest percent of stream miles below the benchmark (30%), and the North Coast had the highest (40%). Likewise, there were no significant differences between the different land use classes and the reference site results. The percent of miles with scores below the benchmark, however, did increase from a low for federal forested land (16%) to a high for agricultural land (63%).

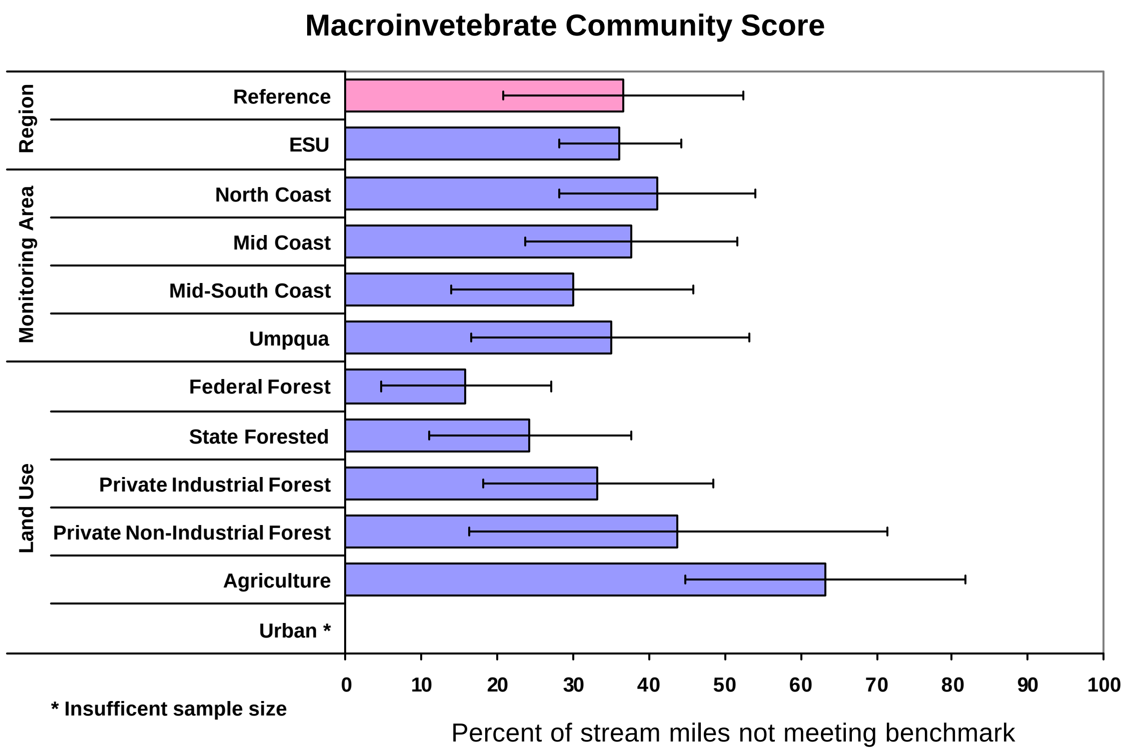


Figure 19. The percentage of stream miles below the benchmark for the macroinvertebrate index across reference streams, the ESU, four monitoring units, and six land use categories. (Error bars represent the 95% confidence interval)

Stressor Extent and Relative Risk – Ranking the Relative Importance of Water Quality Stressors

Besides understanding the status or extent of water quality conditions, it is also important to understand what water quality parameters pose the greatest threat or risk to stream biota. In this context water quality parameters may be thought of as potential stressors to aquatic life. Two factors should be considered when ranking the risk of water quality parameters or stressors. First, is the **extent** of a stressor – how common is a stressor compared to other stressors or at different spatial scales? This information has already been presented for each factor for decline. Second, is the **severity** of a stressor – how much does the stressor effect stream biota?

To assess the severity of stressors we have calculated the "relative risk" of stressors to the aquatic vertebrate and macroinvertebrate assemblages. Relative risk is an approach commonly used to communicate medical and health information. Relative risk can be defined as the probability that the biotic indicator will be poor given poor stressor values rather than good stressor values (Lachin 2000).

Large relative risk values for a parameter mean that the chances of having poor biotic condition are high when that parameter exceeds a certain threshold. For example, someone who smokes two packs of cigarettes a day has an X percent higher risk of lung cancer than someone who doesn't smoke. For this analysis stressors with a relative risk value greater than 1.5, and a 95% confidence interval greater than 1.0, are significant (Stoddard 2003, John VanSickle pers.com.). Relative risk values of 1.0 or less indicate no stressor effect. See Appendix C for information on relative risk calculation.

Stressor Extent:

High water temperature is the most extensive stressor in wadeable coho distribution streams with 53% of the stream miles above the temperature criteria (Figure 10). High total solids, phosphorus and fine sediment are also extensive stressors affecting between 40 to 50% of the stream miles regionally. High nitrogen levels affect about 24% of the stream miles. Dissolved oxygen, non-native species and pH appear to be more minor stressors with less than 10% of the stream miles affected.

Stressor Risk:

Figure 20 shows the extent (left graph) and relative risk scores for macroinvertebrates (middle graph) and aquatic vertebrate assemblages (right graph). Non-native species, total solids, fine sediment and dissolved oxygen have risk factors greater than 1.5 and confidence intervals above 1.0 for the macroinvertebrate community. When these parameters exceed standards or benchmarks there is a significantly increased probability of impairment to the macroinvertebrate community. Although temperature and phosphorus risks exceed 1.5 the error bars extend below 1.0 and are not considered statistically significant risks to the macroinvertebrate community. Nitrogen risk was below 1.0. We had insufficient data to evaluate the stress of pH on macroinvertebrates.

The effect of sediment, both suspended in the water column and on the stream bottom, on the macroinvertebrate community is not unexpected. The habitat niches occupied by most macroinvertebrates are the surface of rocks and the spaces between them. These habitats may be filled in or coated with fine particles when excess sediment is present. Besides lowering habitat quality, fine sediment may also affect oxygen uptake of macroinvertebrates by damaging or interfering with their gills (Ward 1992).

Although very limited in extent, the presence of non-native aquatic vertebrate species ranked as the greatest stressor on the macroinvetebrate assemblage. This may reflect a higher rate of predation on the macroinvertebrates by the alien species, or it may reflect a general decline in habitat conditions that favor non-native fish species and also causes a decline in biotic condition.

The right graph of Figure 20 shows the relative risk of water quality parameters to the aquatic vertebrate community. Total solids, dissolved oxygen, non-native species and pH were statistically significant stressors. pH showed the highest risk factor of the stressors we evaluated. Phosphorus, fine sediment and nitrogen were not significant stressors.

Temperature had relatively high relative risk values for both biotic assemblages (2.2 for vertebrates and 1.6 for macroinvertebrates), but the 95% confidence intervals extended below 1.0, so the risk was not statistically significant. The temperature estimates have larger error bars than other parameters due to the smaller sample size for this parameter.

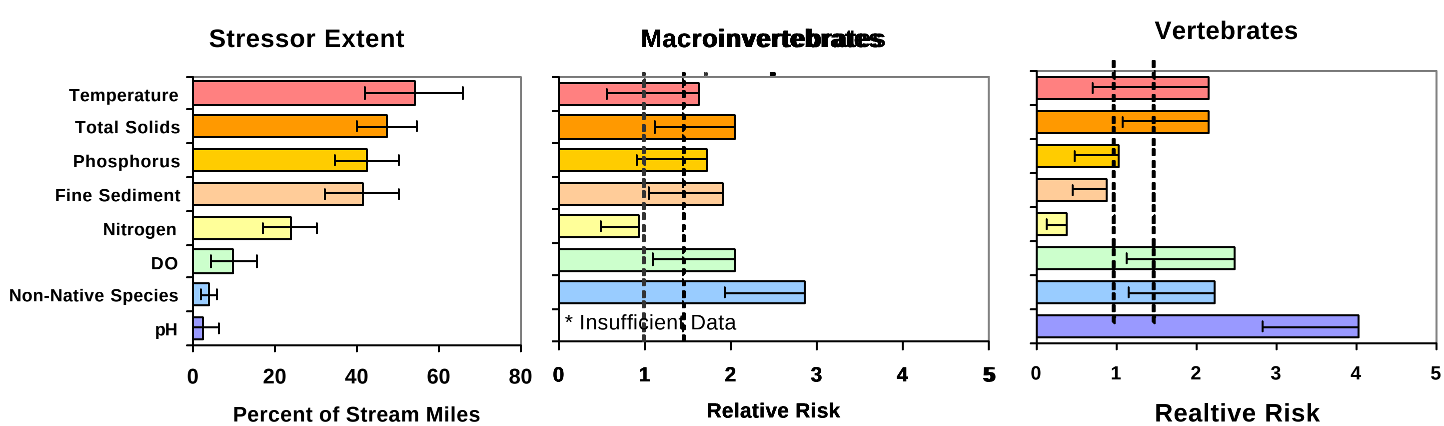


Figure 20. Stream stressor extent and relative risk values for macroinvertebrates and vertebrate assemblages with 95% confidence intervals. Stressors greater than 1.5 with confidence intervals greater than 1.0 are considered significant stressors.

In ranking the relative importance of stressors we took into consideration both the extent and severity (relative risk score) of the stressor. Table 14 is a qualitative ranking of stressors that incorporates both extent and severity of effect. Total solids, temperature and fine sediment rank high in risk because they are both extensive and have relatively high risk factors when present. Phosphorus is of intermediate risk. Dissolved oxygen, non-native species and pH stressors are very low in extent but when present show a high risk to the macroinvertebrate and vertebrate species. Nitrogen ranks the lowest in risk because of low extent and low relative risk.

Table 14. Qualitative relative rank of water quality stressors incorporating extent and relative risk for the macroinvertebrate and vertebrate assemblages.

Relative Rank of Risk	Macroinvertebrates	Vertebrates
Higher Risk	**Total Solids**	**Temperature**
↓	**Temperature**	**Total Solids**
	Fine Sediment	**Phosphorus**
	Phosphorus	**Fine Sediment**
	Nitrgen	**DO**
	DO	**pH**
	Non-Native Species	**Nitrogen**
Lower Risk	**pH (*insufficient data)***	**Non-Native Species**

Land Use and Relative Risk: Ranking the Relative Importance of Land Use Classes

In order to evaluate the relationship of land use classes with stream condition we have treated land use as we did stressors in the previous section, evaluating both the extent of land use classes for coho distribution streams and the conditions of the macroinvertebrate and vertebrate assemblages when those land uses are present (Figure 21).

Private Industrial Forest and Federal Forested lands are the most extensive land uses for coho distribution streams comprising 28.0 and 24.6%% of the stream miles, respectively. The risks to the stream biotic condition for these two land uses are not significantly greater than 1.0 indicating relatively low levels of impairment for these two classes. Agriculture is also a fairly extensive land use for coho distribution streams making up more than 20% of the stream miles. Agriculture land use also shows the greatest biotic condition risk factor of 2.2 to the vertebrate community, and is the only land use with a risk factor significantly greater than 1.0. This indicates a significantly higher probability of impairment to the fish and amphibian assemblage where agricultural land use exists. Private Non-industrial Forest and State Forested are less extensive in the coho distribution comprising 12.9 and 9.6% of the coho streams, respectively. The risk of Private Non-industrial Forest is close to 1.0. The risk of State Forested land is low, especially for the vertebrate community indicating high quality biotic communities in State Forested streams. In general, streams on publicly owned lands showed lower relative risk scores than streams on privately owned lands.

Urban streams were sampled in this study in proportion to their presence in the ESU. Urban land use streams are fairly rare in our sample comprising less than 5% of the coho distribution streams. As a result there are only five urban land use streams in this survey, which is too few to draw conclusions about the condition of urban streams regionally. The data we have from these five streams had high levels of total solids, phosphorus and fine sediment, and macroinvertebrate assemblages with RIVPACS scores below the benchmark.

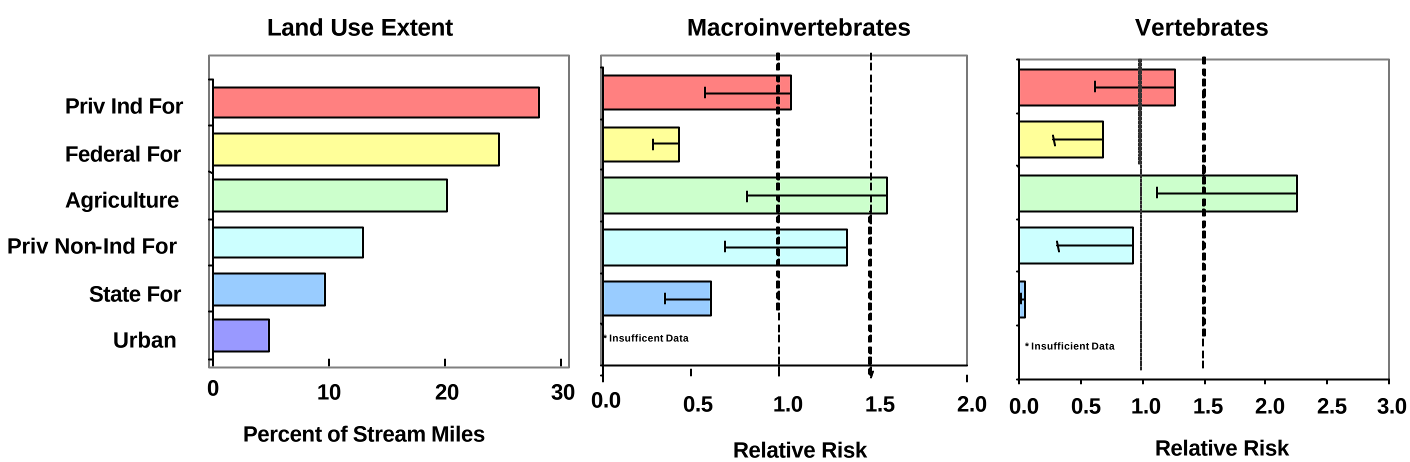


Figure 21. Stream Land Use classes extent and relative risk values for macroinvertebrate and vertebrate communities with 95% confidence intervals. Stressors greater than 1.5 with confidence intervals greater than 1.0 are considered significant stressors.

The ranking of the relative importance of land use classes to stream condition considers both the extent of land uses and their relative risk score to macroinvertebrate and vertebrate assemblages. Table 15 is a qualitative ranking of land uses that incorporates both extent and relative risk score for each land use. Agricultural land ranks highest because of its fairly high extent and higher relative risk when present. Private Industrial Forest is second because of its large extent in the ESU and slightly higher risk scores, though the relative risk scores to biota were not significant. Urban land use was not evaluated due to insufficient data.

Table 15. Qualitative relative rank of land uses incorporating extent and severity of relative risk for the macroinvertebrate and vertebrate communities.

Relative Rank of Risk	Macroinvertebrates	Vertebrates
Higher risk	**Agriculture**	**Agriculture**
↓	**Private Industrial Forest**	**Private Industrial Forest**
	Private Non-Industrial Forest	**Federal Forested**
	Federal Forested	**Private Non-Industrial Forest**
Lower risk	**State Forested**	**State Forested**
Insufficient data	*Urban*	*Urban*

It is important to remember that this assessment of extent and relative risk is based on probabilistic data and not from controlled experiments. It is difficult, if not impossible, to separate the effects of individual stressors and land use practices that can occur together. It is also difficult to use these data to differentiate the effect of significant landscape features, such as lithography, stream gradient and elevation, from land use since these features do not occur independently of each other.

Summary

The probabilistic sample surveys of 1st through 3rd order (wadeable) streams provide an unbiased assessment of the factors for decline across the Coastal Coho ESU. Ambient monitoring sites provide status and trend data for selected large river sites within the ESU. Because ambient monitoring sites were selected non-randomly the results apply to the selected sites only.

At the ESU scale results of the probabilistic surveys for wadeable streams within the coho distribution show:

- Fine sediment, temperature, nutrients, and dissolved oxygen are important risk factors to fish and amphibian and macroinvertebrate assemblages.
- 54% of stream miles exceed the numeric temperature criteria.
- 41% of stream miles exceed the benchmark for fine sediment.
- 10% of stream miles exceed the numeric dissolved oxygen standard.
- 3% of stream miles exceed the numeric pH standard.
- 24% of stream miles exceed the benchmark for nitrogen.
- 42% of stream miles exceed the benchmark for phosphorus.
- 28% of stream miles exceed the benchmark for fish/amphibian assemblages.
- 36% of stream miles exceed the benchmark for macroinvertebrate assemblages.
- 4% of the stream miles have non-native fish and amphibians.

Table 16, summarizes the probabilistic survey results for the ESU, monitoring units and land uses.

Table 16. The percent of coho distribution stream miles in the ESU, four monitoring units, and five land use classes that exceed numeric standards or benchmarks for the factors for decline.

Percent of stream miles that fail to meet standards or benchmarks for the factors for decline.

Monitoring Areas	Temp	DO	pH	Fine Sediment	Total Solids	Nitrogen	Phos	Non-Natives	Verts	Macro-inverts
ESU	54	10	3	41	47	24	42	4	28	36
North Coast	31	6	0	30	33	32	29	2	12	41
Mid Coast	54	12	9	44	33	24	46	1	37	38
Mid-South Coast	44	3	0	40	47	41	23	6	16	30
Umpqua	77	15	0	47	72	6	60	7	40	35
Federal Forested	77	1	0	16	25	28	18	0	18	16
State Forested	*	0	0	16	21	32	3	3	1	24
Private Industrial Forest	43	5	0	45	49	20	54	0	33	33
Priv. Non-Industrial Forest	*	31	13	48	22	7	35	0	43	44
Agriculture	*	13	0	63	73	40	69	12	46	63

* Insufficient data

While conditions between monitoring areas were generally not significantly different, the North Coast tended to have the best water quality conditions and the Umpqua the worst. Likewise, there were few statistically significant differences between land uses, though public lands (State Forested and Federal Forested) tended to have the best conditions and agricultural lands the worst. The assessment of land uses is confounded by natural landscape conditions (geology, elevation, stream slope, etc.), which vary between different land uses and also influence water quality. As a result it is not possible to assess the effects of land use practices with these data.

In most cases the results for monitoring areas and land uses were not significantly different from the results for reference sites from within the coho distribution area of the ESU. As described in the “Reference Site” section, these reference sites were the best available, and represent “least impaired” conditions” rather than “minimally” impaired conditions (Stoddard in press). As a result reference site conditions reflect the effects of both natural and anthropogenic factors.

Based on the relative risk and extent of the factors for decline, fine sediment (both total solids and stream bed fine sediment) and temperature appear to pose the greatest risk to aquatic life (vertebrate and macroinvertebrate assemblages) in the ESU. This suggests that these parameters are also important risk factors to coho.

At the ESU scale ambient water quality for large river sites is characterized by:

- 42% of ambient monitoring sites have excellent to good water quality based on the Oregon water quality index.
- 19% of ambient monitoring sites have poor to very poor water quality.
- The remaining 39% of monitoring sites have fair water quality.
- There are no declining trends in water quality at ambient sites for the 10-year period of 1993 to 2002.
- 39% of ambient sites show a significant improving trend in water quality, and 61% of sites show no change over the 10-year period.
- Total Solids was primary stressor at 58% of large river sites and was the most frequent parameter degrading water quality at large river ambient sites.

Ambient water quality at large river sites for the four monitoring areas show:

- The North Coast sites have the highest water quality and the mid-South Coast and Umpqua sites the poorest water quality.
- North Coast sites show the largest number with improving trends (6 out of 9 sites).
- The Umpqua sites show the lowest number with improving trends (1 out of 9 sites).

References

Allan, J.D. 1995. Stream ecology: Structure and function of running waters. Champman and Hall, London, England.

Beschta, R.L. 1978. Long-term patterns of sediment production following road construction and logging in the Oregon coast range. Water Resources Research 14: 1011-1016.

Bjornn, T. C., M. A. Brusven, M. Molnau, F. J. Watts, R. L. Wallace, D. R. Neilson, M. F. Sandine, and L. C. Stuehrenberg. 1974. Sediment in streams and its effects on aquatic life. Technical Completion Report, Project B-025-IDA. University of Idaho, Water Resource Research Institute, Moscow, ID.

Coutant, C.C. 1987. Thermal preference: when does an asset become a liability? Environmental Biology of Fishes 18(3): 161-172.

Cude, C. 2001. Oregon Water Quality Index: A tool for evaluating water quality management effectiveness. Journal of the American Water Resources Association, 37(1): 125-137.

Davis, W. and T. P. Simon. 1995. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. CRC Press, Inc., Boca Raton, Florida.

DEQ. 2004. Watershed Assessment Section Mode of Operations Manual (MOMs). Version 3.1 03-LAB-0036-SOP. DEQ Laboratory Division, Portland, Oregon.

Drake, D. 2004. Selecting Reference Condition Sites – An Approach for Biological Criteria and Watershed Assessment. DEQ Technical Report WASO4-002. Portland, OR.

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68: 1364-1372.

Hall, J.D., and R.L.Lantz. 1969. Effects of logging on the habitat of coho salmon and cutthroat trout in coastal streams. Pages 355-375 in Northcoate (1969)

Hawkins, C. P., R. H. Norris, J. N. Hogue, and J. W. Feminella. 2000. Development and evaluation of predictive models for measuring the biological integrity of streams. Ecological Applications 10:1456-1477.

Herlihy, A.T., D.P. Larsen, S.G. Paulsen, N.S. Urquhart, and B.J Rosenbaum. 2000. Designing a spatially balanced, randomised site selection process for regional stream surveys: The EMAP Mid-Atlantic Pilot Study. *Environmental Monitoring and Assessment*. 63:95-113.

Hughes, R.M., S. Howlin, and P.R. Kaufann. 2004. A Biointegrity Index for Coldwater Streams of Western Oregon and Washington. Transactions of the American Fisheries Society. 133: 1497-1515.

Hutchinson, G. E. 1957. A Treatise on Limnology, Volume I: Geography, Physics, and Chemistry. John Wiley and Sons, Inc. New York.

Lachin, J. M. 2000. Biostatistical Methods: The Assessment of Relative Risk. John Wiley and Sons, New York.

Meehan, W.R. editor. 1991. Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Society Special Publication 19.

Northcote, T.G., editor. 1969. Symposium on salmon and trout in streams. H.R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver.

Omernik J., T. Thorson, S.A. Bryce, D.A. Lammers, A.J. Woods, J. Kagan, D.U. Pater, and J.A.Comstock. (In press 2004) Ecoregions of Oregon.

Peck, D.V., J.M. Lazorchak, and D.VJ. Klemm (editors). 2000. Unpublished draft. Environmental Monitoring and Assessment Program-Surface Waters: Western Pilot Study Field Operations Manual for Wadable Streams. EPA/XXX/X-XX/XXX. U.S. Environmental Protection Agency, Washington, D.C.

Platts, W.S. 1991. Livestock grazing. Pages 389-423 in Meehan (1991).

Simon, T. P. 1999. Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities. CRC Press. Boca Raton, FL.

State of Oregon. 1997. Oregon Coastal Salmon Restoration Initiative. Oregon Plan for Salmon and Watersheds document, Salem, OR.

Stevens, D.L., Jr., and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association 99:262-278.

Stevens, D.L., Jr, and A.R. Olsen. 1999. Spatially restricted surveys over time for aquatic resources. Journal of Agricultural, Biological, and Environmental Statistics: 415-428.

Stoddard, L. J., J. Van Sickle, S.G. Paulsen, D. Peck, P. Kaufmann, P. Larsen, A. Herlihy, R. Hughes, T. Whittier, G. Lomnicky, S. Pierson. 2003 In press. Mid-Atlantic Integrated Assessment (MAIA) State of the Flowing Waters Report. USEPA Office of Research and Development, Western Ecology Division, Corvallis, OR.

Stoddard, J., P.D. Larsen, C. P. Hawkins, R. K. Johnson, R. H. Norris. In Press. Setting Expectations for the Ecological Condition of Running Waters: The concept of Reference Condition. Ecological Applications.

Suttle, K.B., M.E.Power, J.M.Levine, and C. McNeely. 2004. How Fine Sediment in Riverbeds Impairs Growth and Survival of Juvenile Salmonids. Ecological Applications. 14(4):969-974.

Taniguchi, R., F.J. Rahel, D.C. Novinger, and K.G. Gerow. 1998. Temperature mediation of competitive interactions among three fish species that replace each other along longitudinal stream gradients. Can. J. Fish. Aquat. Sci. 55:1894-1901.

USEPA (U.S. Environmental Protection Agency). 1990. The quality of our nation's water: a summary of the 1988 National Water Quality Inventory. U.S. Environmental Protection Agency, EPA Report 440/4-90-005, Washington D.C

Walker, G.W., and MacLeod, N.S., 1991. Geologic map of Oregon: U.S. Geological Survey, scale 1:500,000.

Ward, J.V. 1992. Aquatic Insect Ecology - 1. Biology and Habitat. John Wiley & Sons, Inc. New York, NY.

Waters, T.F. 1995. Sediment in Streams: sources, biological effects and control. American Fisheries Society Monograph 7. 79-117.