Oregon Hatchery Research Center
2018 Annual Report

To:

Oregon Legislature
State Fish and Wildlife Director
State Fish and Wildlife Commission

By:

Oregon Hatchery Research Center Board

April 24, 2019

Executive Summary

This is the sixth annual report by the Oregon Hatchery Research Center (OHRC) Board to the Oregon Legislature, Oregon Department of Fish and Wildlife Director and the State Fish and Wildlife Commission. Highlights of the report include:

- Continued development of OHRC communications plan and capacity;
- Research activities conducted in 2018 by OHRC researchers and collaborators with relationship to the mission and goals of the OHRC, including:
    - Continued implementation of the OHRC Research Plan which addresses three research areas:
        1. If and how the differences in mate selection between hatchery and wild fish influences the reproductive success of hatchery fish in the wild, and how practices could be improved to increase the reproductive success of hatchery fish;
        2. If and how hatchery rearing practices alter the selection of traits with resultant fitness consequences, and how hatchery practices could be altered to minimize hatchery versus wild fitness differences related to selection in the hatchery;
        3. If and how manipulation of hatchery rearing and water can improve olfactory imprinting by juvenile salmonids and homing of adults to their hatchery of origin.
    - Continued implementation of operational research at the OHRC, including but not limited to:
        1. Evaluation of hatchery brood stock collection method on the vulnerability to angling of Alsea River hatchery steelhead;
        2. Evaluation of pressure-induced triploidy as a management tool to genetically isolate hatchery summer steelhead.
- Activities and the focus for the Board in 2018; and
- Appointment of board members by the ODFW Director.

Introduction:

This report fulfills the Oregon Hatchery Research Center (OHRC) Board's requirement to report to the Legislative Assembly, the State Fish and Wildlife Director and the State Fish and Wildlife Commission each calendar year on the findings of research projects carried out by the OHRC, and any recommendations regarding current hatchery management practices based on the OHRC research projects.

This report constitutes the sixth report of the OHRC Board to the Legislative Assembly, the State Fish and Wildlife Director and the State Fish and Wildlife Commission. In this report, we detail the activities of the OHRC Board during the 2018 calendar year with reference to past activities, describe the funding and implementation of the Research Plan for the OHRC as adopted by the OHRC Board in 2014, report on the position creation and hiring of a joint OSU-ODFW State Fisheries Geneticist, and relate scientific information and recommendations produced through research conducted at the OHRC in 2018. This report also presents the focus for the Board in 2019.

2018 OHRC Board:

Per the direction in HB 3441 for establishing the OHRC Board, the Oregon Department of Fish and Wildlife (ODFW) Director is to appoint a 15 member board consisting of 12 voting members and 3 non-voting members.

The 12 voting members shall represent the following interests:

1) Oregon Salmon Commission
2) Columbia River gillnet salmon fishery
3) wild fish advocacy organizations (2 members)
4) statewide sport angling organizations (2 members)
5) agricultural industry
6) coastal ports
7) forest products industry
8) the independent scientific community
9) fish habitat restoration interests
10) Oregon Indian tribes

The 3 non-voting members of the board shall represent:

1) Oregon Department of Fish and Wildlife
2) Oregon State University
3) federal agency related to fish management

Table 1 identifies the current OHRC Board members as of December 31, 2018, their position descriptions (group representation) and their designated terms. The OHRC Board is currently led by Co-Chairs Brad Halverson and Kyle Smith.

Table 1: OHRC Board members by interest group and term of appointment.

Position	Member	Term
Oregon Salmon Commission	Dwight Collins	07/01/21
Columbia River Gillnet	Vacant	
Wild Fish Advocacy	Brad Halverson	07/01/19
Wild Fish Advocacy	Kyle Smith	07/01/21
Sport Angler	Jack Smith	07/01/19
Sport Angler	Lindsay Ball	07/01/21
Agriculture	Ted Simon	07/01/20
Coastal Ports	Chuck Pavlik	07/01/20
Forestry	Scott Starkey	07/01/19
Independent Science	Steve Jacobs	07/01/21
Habitat Restoration	Vacant	
Tribes	Maureen Hess	07/01/20
Federal Agency	Craig Busack	Indefinite, non-voting
OSU	Carl Schreck	Indefinite, non-voting
ODFW	Bruce McIntosh	Indefinite, non-voting

OHRC Board Terms Expiring and Resignations:

Ted Simon was appointed to the OHRC Board in 2018 as representative of the Agricultural Industry. Cam Parry's resignation from the Board rendered the Habitat Restoration position vacant, and ODFW is working to recruit a new member for this position as well as for a representative of the Columbia River gillnetters.

OHRC Board Activities in 2018:

Overview

The OHRC Board oversaw the implementation of the OHRC Research Plan throughout 2018 with regular updates provided at each Board meeting. The Board continued work during the year on a communications plan for the OHRC to ensure public support and funding for the important work conducted at the OHRC.

Board Meeting Highlights

The OHRC Board met during each quarter of 2018 to assess progress on research conducted at and through the Center, review scientific publications and other information pertinent to hatchery management, and attend to business related to Board governance and OHRC operation.

On February 6, 2018, the Board met at the ODFW South Willamette Watershed District Office in Corvallis, Oregon. At this meeting Drs. Heather Auld (Dr. Banks Lab), Michael Blouin and David Noakes provided updates on their respective research projects related to effects of mate

selection, domestication and olfactory imprinting on hatchery-reared salmon and steelhead. Marc Johnson led a discussion of a recently published article that reported differences between gene expression patterns of hatchery and wild salmon. Representatives from Weyerhaeuser provided the Board with an update of a massive landslide located one mile upstream from the OHRC, and their efforts to install a landslide monitoring system and alarm. At this meeting Cam Parry announced his impending departure from the Board. Brad Halverson and Kyle Smith were elected co-chairs of the Board, and Ted Simon joined the Board as representative of the Agricultural Industry. After providing an update on budget issues related with the OHRC, Kevin Goodson announced he would be retiring in May of 2018, after 35 years of service with ODFW. The minutes of this meeting have been posted online and can be accessed at: https://www.dfw.state.or.us/fish/OHRC/docs/2018/OHRC_BoardMeetingMinutes_020618_Final.pdf

The OHRC Board met on April 3, 2018 at ODFW Headquarters in Salem, Oregon. Co-chair Brad Halverson reviewed the mission of the Board and emphasized the Board's role as related to fundraising, research, implementation and outreach. ODFW Fish Division Administrator, Ed Bowles spoke about the importance of the OHRC and its value to hatchery science and management. Guido Rahr, President of the Wild Salmon Center spoke about salmon conservation in Oregon and around the Pacific Rim. The Board received updates on progress toward implementing the OHRC Research Plan from Drs. Auld (Banks Lab), Garvin (Blouin Lab) and Noakes. The Board also received an update on the landslide near the OHRC from Bruce McIntosh and Joseph O'Neil, who also reported on the hiring of a new hatchery technician at the Center. Minutes from this OHRC Board meeting are available at: https://www.dfw.state.or.us/fish/OHRC/docs/2018/OHRC_BoardMeetingMinutes_040318_Final.pdf

The Board met again on September 18, 2018 at the OHRC. Joseph O'Neil reported on several operations and maintenance projects at the OHRC, including stream bank stabilization and hatchery water intake improvements. Bruce McIntosh reported on the status of the nearby landslide. Jen Krajcik provided an update on the OHRC's Education and Outreach Program and emphasized measures taken at the OHRC with regard to visitor safety. The Board engaged in a discussion with ODFW staff (Drs. Bruce McIntosh and Marc Johnson) about applying information gained from short-term OHRC research at ODFW hatcheries. Board member, Maureen Hess, presented finding from her research using parental-based (genetic) tagging to monitor salmon and steelhead populations in the Columbia River. The Board also received updates from the ongoing OHRC research projects led by Drs. Noakes, Banks and Blouin. Minutes from this OHRC Board meeting are available at: https://www.dfw.state.or.us/fish/OHRC/docs/2018/OHRC_BoardMinutes_091818_Final.pdf

The final OHRC Board meeting of 2018 was held on December 4th at ODFW Headquarters in Salem, Oregon. At this meeting, OHRC facilities manager Joseph O'Neil reported on completion to water intake upgrades at the OHCR and installation of a new water elevation alarm to warn in the event of a landslide that could potentially block Fall Creek and impact the facility, then announced that he planned to retire at the end of December. Dr. David Noakes reminded attendees that the Fall Creek road had been paved, and that they should be cautious of logging trucks that regularly use the one-lane road. Bruce McIntosh reported on the status of the

landslide near the OHRC and plans by ODFW to monitor the slide with drone imagery. The Board received updates from researchers implementing the OHRC Research Plan. Dr. Maryam Kamran (Noakes Lab) reviewed the objectives of the Olfactory Imprinting Project and presented results from her tests of over 20 candidate odorants involving about 7,000 subject fish. She also informed that Oregon Public Broadcasting (OPB) had recently released a story about telemetry study of Elk River Chinook salmon that would provide baseline information for the Olfactory Imprinting Project (https://www.opb.org/news/article/salmon-chinook-oregon-pacific-hatchery-osu-research-scent/). Dr. Michael Blouin presented an update on his Hatchery Domestication Selection Project, emphasizing his interest to study boldness behavior in hatchery steelhead and how findings could relate to previously described variation in fitness. Dr. Blouin also introduced a new member of his research group, Dr. Chris Holland. Dr. Heather Auld provided an update of progress made by Dr. Michael Banks' Mate Choice Project. She and Dr. Banks continue to search for the most appropriate venue (hatchery) for the second and third stages of their project, wherein they plan to use genetic data to inform which fish should be crossed during hatchery spawning, and evaluate the effectiveness of informed crosses on fitness. Austin Huff (ODFW) provided an overview of telemetry-based research of Chinook salmon, which will be used to describe baseline migratory behavior of wild and hatchery salmon in the Elk River, prior to any treatments applied through the Olfactory Imprinting Project. Dr. Marc Johnson presented information about best practices for the use of wild fish in hatchery brood stocks, emphasizing the need to evaluate integrated hatchery programs in context of desired outcomes. Dr. Noakes and Joseph O'Neil led a discussion with the Board about the nature and importance of operational research. The minutes from this meeting can be accessed at: https://www.dfw.state.or.us/fish/OHRC/docs/2018/OHRC_BoardMinutes_12042018_Final.pdf

OHRC Board Focus in 2019:

The OHRC Board will continue to focus on outreach, education and fundraising for the OHRC. The Board will also continue to advise ODFW, OSU and the OHRC Director on priorities and research implementation opportunities through the OHRC.

OHRC Activity Report 2018:

Overview

The most important activities conducted byt the OHRC Board in 2018 related to implementation of the OHRC Research Plan. The Plan, as approved in 2014, describes the OHRC's goals and related research projects. It is available for viewing or download online at https://www.dfw.state.or.us/fish/OHRC/docs/2016/OHRC_Research_Plan.pdf. Funding to support the Research Plan was confirmed on July 1st, 2015, subject to formal agreements between ODFW and Oregon State University. Each of the three principal investigators identified through the Plan (Drs. Banks, Blouin, and Noakes) successfully completed international searches for Postdoctoral Research Scholars in 2016 to assist with their respective research projects. Expenditure of research funds on personnel, supplies and operations commenced after approval by Oregon State University (January 2016) and continue through the present.

The research topic called for in the OHRC Research Plan and led by Dr. Michael Blouin (differences caused by hatchery rearing, or domestication selection) continued to be addressed as planned. The premise of this work is that larger size of juvenile steelhead and salmon at time of release from hatcheries is favored because it predicts greater survival at sea. Therefore, traits that allow fast growth in the novel environment of a hatchery are likely to be under selection. Dr. Blouin's lab is taking two approaches to investigate sources of growth variation and mechanisms of selection. Firstly, they are testing whether various modifications to the hatchery environment can reduce the variance among families in size at release, which would reduce the opportunity for selection after release. So far they have rejected the hypothesis that raising fish under low density would achieve that goal. They are testing various other environmental manipulations. Secondly, they are measuring various traits on families that are grown in the hatchery to see if variation in those traits predict which families grow fastest. This would identify traits that are potentially under selection. For now they are focusing on behavioral traits. In particular, they are testing the hypothesis that hatcheries select for excessively bold behavior.

The Research Project headed by Dr. Michael Banks (genetics and mate choice) progressed as planned during 2018. Drs. Banks and Auld have successfully analyzed two 10-year genetic pedigrees to identify genetic markers significantly associated with mate choice and differential reproductive success in coho salmon from the Umpqua River and spring-run Chinook salmon from the McKenzie River. They co-authored a review of mate choice studies in salmon that was accepted for publication, and a manuscript detailing findings from the coho salmon pedigree (in review). Their findings were presented at meetings of the International Society for Behavioral Ecology and the American Fisheries Society. Drs. Banks and Auld visited three (Rock Creek, Morgan Creek and McKenzie) hatcheries to evaluate them as potential sites for phase three of their project, which will test for differential reproductive success in side-by-side comparison of 'wild-like' informed mating (based on findings from the pedigrees) against random based selections of mates, as is standard protocol in most hatcheries. They also compared and contrasted alternate molecular techniques for efficient, cost effective characterization of hatchery returns. They selected GTseq as the best means of providing this information. They are thus prepared and in position for phases 3 of their project, wherein they will use GTseq to inform 'wild-like' mating selections in a hatchery context in fall of 2019.

The Research Project headed by Dr. David Noakes involved collaborations with colleagues from the University of Washington (Seattle), NOAA (Seattle), the Leipzig Institute (Berlin, Germany) and ODFW. They completed the second year of water samples from the Elk and Sixes rivers in southern Oregon to determine the chemical nature of the river water at the time of migration by juvenile smolts and of returning adult Chinook salmon. The water samples are being analyzed (amino acids, dissolved organic matter, dissolved carbon compounds) to characterize the various river tributaries in relation to the numbers of returning hatchery-origin Chinook salmon that stray into each tributary. The second year of testing behavioral responses of young Chinook salmon to selected test chemicals took place at the OHRC. We also measured the olfactory receptor responses of salmon to selected chemicals in the NOAA (Seattle) laboratory. Chinook salmon embryos from the ODFW Elk River Hatchery were brought to the OHRC where they were reared under controlled conditions prior to testing their behavioral responses to test chemicals. Detailed testing of conditioning responses of young Chinook salmon to selected test chemicals was completed during 2018. Chinook salmon from Elk River parents were reared under standard

production hatchery procedures at the ODFW Elk River Hatchery and under comparable conditions at the OHRC. Fish at both localities were sampled at regular intervals to measure the development of olfactory nasal receptors. In addition, some fish at the OHRC were exposed to a selected chemical (arginine) during development to provide comparisons of olfactory organ development in control fish.

Detailed schedules, timelines and research activities for all three Research Projects are provided as Flow Charts in the Research Plan[1]. Progress reports for each of the three Research Projects were presented to the OHRC Board during the regularly scheduled Board meetings of 2018. In addition, all members of the three Research Projects met at bimonthly intervals to update on research results, coordinate research activities and plans. Reports of those meetings were provided to the OHRC Board at their regular, quarterly meetings.

ODFW worked closely with the OHRC and OSU to create a State Fisheries Geneticist position that was partially funded by the 2015 Oregon Legislature. In 2017, Dr. Kathleen O'Malley was hired to fill this position, which is jointly supported by ODFW and OSU. Dr. O'Malley has, since that time, expanded capacity for genetic analyses to support Oregon fisheries research through extramural collaboration, the hiring of staff, development of an extensive database, elaboration of sampling protocols, and much more. Research being conducted by the State Fisheries Geneticist currently includes genetic pedigree studies to support reintroduction of Chinook salmon above dams in the upper Willamette River, analyses of genetic connectivity in marine species (including Dungeness crab, albacore tuna and Deacon rockfish), and investigations into the effects of climate change on genetically-modulated fish behavior. More information about the research being conducted through the State Fisheries Genetics Laboratory can be obtained through their website at https://agsci.oregonstate.edu/state-fisheries-genetics-lab/research-areas.

The OHRC further addressed its Mission[2], as approved by the OHRC Advisory Board, through Research Projects, Research Workshops, Educational Projects and Outreach Activities. This involved active research collaboration with colleagues from the Oregon Department of Fish and Wildlife, the Oregon State University, the University of Oregon, the US Geological Survey, the US Fish and Wildlife Service, NOAA Fisheries, the University of Hawai'i, the University of North Carolina, the University of Washington, the Makah Tribal Fisheries, the Liepzig Institute of the University of Berlin (Germany), the University of Miami, North Carolina State University, Dartmouth College, the USFWS (Vemont) and the University of California – Davis. Several postgraduate students, postdoctoral research scholars and technical staff, supported by external funding, have contributed to these efforts as well. Drs. Michael Banks, Michael Blouin, Kathleen O'Malley, Andy Dittman, Jessica Miller, Tom Quinn, Ken Lohmann, Kathleen Cole, Ben Clemens, Jason Dunham, Nathan Putman, Karen Cogliati, Camille Leblanc and Marc Johnson are the principal collaborators on these research projects. We attracted about $1.5 million for educational and research activities in 2018 with numerous collaborators at the OHRC from a variety of sources, including the National Science Foundation, the Bonneville Power Administration, the US Army Corp of Engineers, Oregon Sea Grant, ODFW Restoration and Enhancement Program and international funding sources. Results of our activities were reported

[1] https://www.dfw.state.or.us/fish/OHRC/docs/2016/OHRC_Research_Plan.pdf
[2] https://www.dfw.state.or.us/fish/ohrc/mission.asp

to the OHRC Board, to ODFW, to local, regional, national and international meetings and were published in the primary scientific literature.

The activities described above and in Appendix 1 occurred during 2018. Activities and research results that have taken place in previous years can be found on the OHRC website at: http://www.dfw.state.or.us/fish/OHRC/news.asp. These earlier reports illustrate the progression of research activities at the OHRC, as well as development and funding of the OHRC Research Plan.

OHRC Mission

The first goal in our Mission is to:

1. **Understand mechanisms that may create differences between hatchery and wild fish.**
    a. Determine the process and rate by which wild fish may change in the hatchery environment within and across generations.
    b. Determine the process, rate and pattern by which hatchery-produced fish adapt to the natural environment at each life history stage.
    c. Determine the possible genetic and ecological consequences of hatchery fish and their releases on native fish at each life history stage.

We have addressed these Mission statements with the following research projects in 2018:

1.a. Domestication selection (steelhead) – Blouin, Noakes
1.a., b. Non-genetic influences on early growth and development (Chinook, steelhead) – Schreck, Noakes, Cogliati
1.b. Effect of climate change on development and sex change (steelhead) – Cole, Schreck, Noakes, Blouin
1.b. Steelhead wild surrogates – Schreck, Noakes, Cogliati
1.b. Chinook wild surrogates – Schreck, Noakes, Cogliati
1.b. Behavior and survival of hatchery and wild steelhead smolts – Schreck, Noakes, Thompson, Leblanc
1.c. Alsea steelhead population genetics – Banks, O'Malley, Noakes
1.c. Angler harvest of Alsea River steelhead – OHRC, ODFW
1.c. Homing and straying in Chinook and steelhead – Noakes, Putman, Dittman, Johnson, Schreck, Kamran

The second goal in our Mission is:

2. **Develop approaches to manage hatchery fish that conserve and protect native fish.**
    a. Determine hatchery breeding, rearing and release practices that allow hatchery-propagated fish to both contribute to fisheries and facilitate the conservation and recovery of naturally produced native fish.

1. Identify possible effects, both locally and on a landscape scale, to natural ecosystems associated with different types and levels of hatchery production and identify approaches to manage these effects.
2. Identify hatchery practices that may need to be altered in response to changes in the natural environment and other external factors.

b. Identify breeding, rearing and release protocols that minimize possible adverse impacts on the natural ecosystem.
c. Evaluate the effectiveness of producing hatchery fish, relative to other strategies, as a means to achieve commercial, recreational, conservation and ecological objectives.
d. Determine the effects of hatchery operations (for example: flow alteration, effluent water quality, pathogens, migration and spawning distribution, etc.) on native fish, aquatic communities and their habitats.

We have addressed these Mission statements with the following research projects in 2018:

2.a.1. Downstream migration and survival of steelhead smolts – Noakes, Schreck, Leblanc, Thompson
2.a.1.2., 2.b. Alsea steelhead angler harvest – ODFW, OHRC, Noakes, Johnson, Alsea Sportsmen's Association
2.b. Mate choice – O'Malley, Banks, Auld, Noakes
2.b., c. Behavior of hatchery steelhead – rearing conditions- Noakes, Schreck, Sharpe, Cogliati
2.b.,d. Sterile triploids - homing and straying (steelhead) – Johnson, Dittman
2.d. Olfactory imprinting and homing (Chinook, steelhead)– Dittman, Johnson, ODFW, OHRC, Noakes, Kamran
2.d. Geomagnetic imprinting and navigation (Chinook, steelhead) – Noakes, Putman, Scanlan, Pollock
2.d. Life cycle monitoring (steelhead) – Clemens, ODFW, Noakes, Schreck, Sharpe
2.a, d, d Radio telemetry study of both wild-origin and hatchery-origin Chinook salmon in the Elk River

The third goal in our Mission is to:

3. **Educate and train students, fishery biologists, managers and the public on the relationship between hatchery and wild fish, the connection between fish and watershed, estuarine and ocean systems, and the implications for fish management and stewardship.**
    a. Train the next generation of biologists and managers, ODFW and OSU staff through undergraduate, graduate, and continuing education programs and classes at the facility.
    b. Provide educational facilities and programs for K-12 students.
    c. Design and manage the facility to provide an environment of passive and active learning for visitors.

d. Provide opportunities for educators and others to use the OHRC for meetings, workshops and programs that further public understanding of the relationship between fish and watershed health.
e. Help facilitate and coordinate on the ground efforts of groups and individuals that have a key interest in our fisheries and fish management.
f. Knowing that our wild and hatchery fish are a vital part of each Oregonian's heritage, we will develop critical hatchery science to be used as applied knowledge for creating policy and management goals that strengthen, support and conserve our fish.
g. Conduct outreach in the communities impacted by wild fish or hatchery release issues.
h. Share research results through both publications and presentations on the local, state and international level.

We have addressed these Mission statements with the following activities in 2018:

3.a. We continue to host student interns from local Community Colleges for technical training and research experience. Each year, we have developed research projects for individual student interns, in collaboration with colleagues from Mt. Hood Community College to address a variety of practical hatchery rearing questions.

3.b. We continue to host tours of the OHRC facility for K-12 students and provide education both onsite and through outreach activities in Oregon

3.c. We continue to host visiting student groups from China and Japan. In particular, an elite academic group (NITOBE College) from the University of Hokkaido, Japan comes to the OHRC at least once each year for a residential educational course.

3.d. We hosted a Research Workshop meeting on diet and feeding, organized by Drs. Carl Schreck and David Noakes, to address the increasing interest on these studies at the OHRC. Reports of all Workshops are presented to the OHRC Advisory Board, and are recorded (video and audio) for any future references. Workshops typically lead to reports in various media outlets, and often form the basis for new research collaborations. In 2018 we hosted a number of media specialists for Marine Media Day, which led to a collaboration with reporter Jes Burns and a feature presentation on OPB, with stories on radio and in print media.

3.e. During 2018 we hosted invited seminars by several high profile colleagues (Dr. Barbara Zimmerman – fisheries and indigenous peoples; Dr. Tom Quinn – salmon ecology and behavior; Dr. Tom Lovejoy – the person who originated the term biodiversity; Dr. Stephanie Yue Cottee – animal welfare and production systems).

3.f. Research conducted through the OHRC was published and presented at numerous scientific workshops and symposia during 2018.

3.g. We give regular presentations to various stakeholders, community organizations and local residents in Port Orford twice each year on our olfactory imprinting study at the ODFW Elk River Hatchery. Meetings between OHRC researchers and local STEP groups have informed on opportunities for research and improved hatchery management in 2018.

3.h. Results from OHRC-based research were described in multiple manuscripts submitted for publication in 2018, including a review of mate choice studies co-authored by Dr. Michael Banks and an analysis of salmon straying behavior in the Elk River that was co-authored by Dr. David Noakes. Innumerous scientific presentations were made by OHRC-affiliated researchers at conferences, meetings and workshops, as described below and in Appendix 1 of this report.

The OHRC is a clearinghouse for, and helps facilitate, research in Oregon related to the management of hatchery fish. Research results and new techniques/technologies from these studies are shared with ODFW administrators, managers, biologists and fish culturists, as well as scientists and biologists around the world, through publications and presentations of research conducted through the OHRC. Administrators and managers review these results and their applicability to hatchery programs and fish management, and direct changes to be made whenever appropriate.

The OHRC continued activity in Education and Outreach and Research Workshops based on both operational and basic Research at the OHRC. The Center maintained active educational programs at every level from kindergarten to post-graduate university students, hosting visits by research collaborators from diverse countries and states to discuss research proposals and projects in 2018. The OHRC published and distributed information about its activities on its website, through local newsletters and brochures, and in books and journals in the primary scientific literature. In 2018, the OHRC contributed articles to various newsletters to describe Center research, education and outreach activities. Researchers from the OHCR made a number of presentations to Oregon coastal elementary and secondary schools.

During 2018, the OHRC hosted school visits, participated in educator training, and coordinated professional activities with students and teachers. OHRC personnel participated in numerous outreach activities with the local community, ODFW staff, and colleagues from universities and research organizations both domestic and foreign. In 2018, OHRC hosted visiting researchers, university and school groups, and made visits and invited presentations to services clubs, angler organizations and educational institutions. OHRC researchers participated in local, regional, national and international research meetings, where they presented results of OHRC educational and research activities.

The OHRC hosted visits from colleagues from across Oregon, the USA, Canada, Japan, and China. Many of these visits led to funding applications for new research projects by our collaborators who plan to come to the OHRC to conduct joint research that takes advantage of our unique facilities. We remain active in publishing the results of our research in a number of international scientific journals and printed books and reports. Dr. Noakes continues as Editor-in-

Chief of the international journal, *Environmental Biology of Fishes*, and the monograph series, *Fish and Fisheries*.

Funding

Operations

The OHRC received a biennial operating budget of approximately $1 million from the Oregon Department of Fish and Wildlife for 2017 - 2019. That support was supplemented by funds provided by the Fisheries and Wildlife Department of Oregon State University, through a Memorandum of Understanding with the ODFW.

Research

During 2018, the OHRC attracted significant extramural funding from a variety of local, state, national and international sources. Much of that funding was leveraged by in-kind support from the OHRC and OSU budget sources (personnel, facilities, operations). The number of research projects continued at a high level, with numerous active projects in 2018. Funding for OHRC activities came from a number of sources. The major operational funding was the biennial budget allocation from ODFW, with contributions from OSU. That funding supported a number of projects at the OHRC, including continued studies to evaluate: the use of induced triploidy as a genetic risk management tool for anadromous fishes, and the heritability of vulnerability to angling in hatchery steelhead (a.k.a. "the Biter Study"). OHRC researchers also received specific funding for individual projects from external sources. For example, the US Army Corps of Engineers awarded Drs. Noakes & Schreck $810,000 per year to conduct the Chinook and steelhead wild surrogate projects. The ODFW Restoration and Enhancement Board awarded Kevin Goodson (ODFW) $99,480 to conduct a radio telemetry study of adult Chinook salmon on the Elk River in the winter of 2018 – complimentary to Dr. Noakes' Olfactory Imprinting Project. OHRC researchers also received funding from ODFW, through Legislative allocations, to support the three Research Projects of the Research Plan ($600,000 for 2018). In addition, a number of collaborators brought their own funding for research projects at the OHRC: Dr. Desiree Tullos – NSF, Dr. Arimune Munakata – JSPS, Dr. Michael Blouin – BPA, Dr. Kathleen Cole – University of Hawaii, Dr. Michael Banks – COMES, Dr. Marc Johnson – ODFW, Dr. Ken Lohmann – University of North Carolina. OHRC researchers supported a number of graduate students with individual awards to them as fellowships and scholarships. Many of these postgraduate students are supported by Graduate Teaching Assistantships from Oregon State University, and some have scholarships or other financial awards from a variety of sources.

Education and Outreach

The OHRC has been the principal partner with the Lincoln County and Tillamook County School Districts in the OCAMP and Oregon Coast STEM Project. The Oregon Coast STEM Center project received funding for Lincoln County & Tillamook County School Districts (Dr. Noakes is a Co-PI on this project with Ruth McDonald and others; total awarded $1.3 million over most recent 8 years for OCAMP, STEM) with 20 partners now engaged in the Oregon Coast STEM HUB Center.

The OHRC also hosts an annual Free Fishing Day in June each year, and a Fall Festival in November. On those occasions we are open to the public and host 200 – 300 people, including many families. In 2018 we were involved in organization and hosting of the annual research conference of graduate students in the OSU Fisheries & Wildlife Department (RAFWE).

Management Recommendations in 2018 Based on OHRC Research Findings

Research conducted at the OHRC in 2018 advanced knowledge of tools that will be used to both understand and manage potential risk from hatchery salmon and steelhead. OHRC researchers shared their results with the Board and with ODFW managers on many occasions to evaluate opportunities for implementation and research that could prove useful to hatchery management. Dr. Marc Johnson (ODFW Fish Division Liaison to the OHRC) organized and held the first ODFW-OHRC coordination meeting to facilitate communication between ODFW managers and OHRC researchers on September 13th, 2018. This meeting was held at the ODFW Corvallis Research laboratory and was attended by Ryan Couture, Manny Farinas, Andrew Gibbs, Jen Krajcik, Marc Johnson and David Noakes. Participants discussed opportunities to improve OHRC education and outreach objectives, hatchery research implementation and communication. Participation by Drs. Noakes and Johnson at the upcoming West Region Hatchery Managers Meeting (June 25th, 2019) was also scheduled.

Preliminary results from the Olfactory Imprinting Project led by Dr. Noakes found that juvenile salmon can learn the chemical nature their natal water during incubation and hatching. Results from this study further suggested that young salmon incubated in well water do not develop "olfactory memories" of their source hatchery. These findings were published in the journal Fisheries[3] and shared with ODFW managers, which prompted several hatchery managers to modify their practices by using river water to incubate salmon eggs at their facilities with the objective of improving homing to the hatchery by these fish. In a production-scale test of this experimental practice, ODFW has incubated a portion of the Chinook salmon it produced in 2017 and 2018 in river water, to compare homing and straying rates of these fish to those of fish incubated in well water. Experimental fish will be identifiable by uniquely marked coded wire tags to facility data collection.

Building upon results from OHRC research that elucidated the ability of salmon to detect and use geomagnetic cues to navigate during the ocean phase of their migrations[4], colleagues from the University of North Carolina, and LGL Environmental Research carried out tests of the orientation responses of juvenile Chinook salmon after exposure to pulsed magnetic fields. The results are consistent with the hypothesis that the mechanism for geomagnetic orientation in these fish is based upon magnetite crystals in receptor organs. These results may have implications over the materials used in the future to construct salmon hatchery and rearing facilities.

[3] https://www.dfw.state.or.us/fish/OHRC/docs/2015/Dittman_et_al%20_2015_Fisheries.pdf
[4] https://today.oregonstate.edu/archives/2014/feb/study-confirms-link-between-salmon-migration-and-magnetic-field

Research conducted through the OHRC by graduate student (M.Sc.) Michelle Scanlan examined the effects of coded wire tags on the orientation responses of juvenile Chinook salmon and steelhead. Results from her work will be shared with hatchery managers and ODFW biologists for their consideration.

Appendix 1: Detailed Activity Reports for the OHRC

OHRC Mission Goals 1 and 2: Research Projects

Research Projects at the OHRC are reviewed according to our Mission Statement, current priorities, funding and the availability of personnel and facilities. All research projects are reviewed by ODFW, OHRC staff, the Director and the OHRC Board, and are required to provide updates and final reports. Current Research Projects can be grouped by categories related to the OHRC's mission and goals.

Details of the Proposals, Progress Reports, Completion Reports and resulting publications are available on the OHRC website[5], and in the records of the previous OHRC Advisory Committee. Many of those Reports include Recommendations that were made to the ODFW or other agencies for consideration or implementation. Results of our activities are reported at annual ODFW Meetings (hatchery managers and regional fish biologists in alternate years).

Individual Research Projects

A number of research projects were being conducted at or by affiliates of the OHRC in 2018. Those projects are described below, with details provided by researchers for each project as appropriate:

(1) Olfactory imprinting (Mission Goals 1.c., 2.d)

This OHRC research project addresses a high priority request from ODFW to provide recommendations for their management of hatchery salmon and steelhead, which may stray and interact with wild fish on spawning grounds. We began research on this project in 2012. Funding is provided from the OHRC – OSU operating budget, with support in kind provided by ODFW hatcheries, NOAA (NWFSC), and OSU. This project expanded in 2016 with allocation of long-term research funds from the Oregon Legislature. Our collaborators include Dr. Andy Dittman (NOAA, NWFSC, Seattle), Dr. Gabriel Singer (Leipzig Institute, Berlin, Germany), OHRC, ODFW and OSU personnel. All of our collaborators provide support directly and in kind for time, equipment and personnel. A continuing postgraduate student, Kate Self, supported by US ACOE funding and a scholarship from NSF – JSPS, carried out her M. Sc. research with this group. She spent summer 2016 working with collaborators at Hokkaido University, Japan on part of their research project and then continued her studies at OSU in 2017 and completed her M.Sc. degree in 2018. Our research collaborators at Hokkaido University have established an ongoing exchange with OSU, as well as the summer research program in Sapporo, Japan. She found that genetic activity in the brains differed between migratory and hatchery juvenile Chinook salmon. She prepared those results, together with the rest of her M. Sc. research, for her thesis defense. We have presented a number of progress reports at local, regional and national research meetings, and at invited presentations to university classes, school groups, angler clubs, Willamette Fisheries Science Review and ODFW Hatchery Managers. The first manuscript from this project was published in Fisheries (Dittman et al. 2015). Oral papers from this project were presented during 2018 at the Oregon Chapter of the American Fisheries Society and the biennial conference on Ecology, Ethology and Evolution of Fishes. We have shown that both Chinook salmon and steelhead imprint on the water in which they are incubated, from fertilization to swim up stage. Fish imprint strongly on river water, but not on well water. We have verified our findings at both the OHRC and at the ODFW Leaburg Hatchery on the McKenzie River, Oregon.

[5] https://www.dfw.state.or.us/fish/ohrc/

The critical step in this research will now be to be to rear large numbers of salmon and steelhead at a selected ODFW hatchery (Elk River) in the two sources of water, mark them accordingly and release them as smolts. The homing/straying of the returning adults may determine whether ODFW, and possibly other agencies, change hatchery practices. This forms part of the proposed Research Plan activity for the OHRC (details elsewhere in this Report).

(2) Geomagnetic imprinting (Mission Goals 1.c, 2.d)

Our research on this topic is also in response to a priority request from ODFW to provide recommendations for their management of homing and straying in wild and hatchery salmon and steelhead. This research has produced the first evidence that salmon and steelhead use geomagnetic cues for their orientation and navigation, from embryos to adults. A series of papers has been published from this research, and more are in progress (Putman et al. in prep). Results from that work have been presented at regional, national and international research conferences. We have shown conclusively that Chinook salmon, sockeye salmon, pink salmon, Atlantic salmon and steelhead use geomagnetic cues to orient their movements and navigation from the time of hatching until their return as adults. Our publications have attracted a considerable level of interest because we are the first to demonstrate that salmon and steelhead use geomagnetic orientation (several hundred web sites list our research papers already). Michelle Scanlan and Amanda Pollock, supported by funding from the US ACOE and the OHRC are continuing their analyses of these studies for publication. Our findings have very significant implications for both wild and hatchery salmon and steelhead. We have shown experimentally that rearing young fish in a hatchery environment with conventional equipment and facilities impairs their ability to use geomagnetic cues to orient and navigate. We predict that any interference or disruption of the geomagnetic cues would potentially cause significant impairment of homing in both wild and hatchery fish. Sources of such disruption would include iron reinforcement bars in concrete buildings or raceways, transport of smolts inside steel barges, passage of smolts or adults through hydroelectric dams or operation of wave energy structures or undersea electrical cables. In a similar manner, wild fish could be affected by any disruption of their magnetic environment during their migrations as smolt or adults (e.g., passage through hydroelectric dams, proximity to wave energy structures or electrical cables). We are continuing these experiments to compare a life cycle testing of the homing and straying of fish reared under normal and disrupted magnetic fields. This will require cooperation with ODFW production hatcheries, to produce the numbers of fish for life cycle testing, and will have to extend over at least one life cycle of the fish to determine the effects on returning adults. Michelle Scanlan's research investigated the effects of coded wire tags on the magnetic responses of juvenile salmon and steelhead. Coded wire tags are strongly magnetic, and they are inserted into the nasal region of the fish, where the magnetic receptors are probably located. Results from her study will certainly have very significant implications for the large scale marking of hatchery fish with coded wire tags. Our research on olfactory imprinting and geomagnetic orientation were the basis for oral and poster presentations at the Oregon Chapter of the American Fisheries Society, and oral papers at the international biennial research conference on Ecology, Ethology and Evolution of Fishes (Concordia University, Montreal, Canada).

(3) Surrogates for wild Chinook salmon (Mission Goals 1.b., 2.a.2., 2.b., 2.d.)

This project is a continuing, multi-year project by Drs. Carl Schreck and David Noakes, supported by funding from the US Army Corps of Engineers (Willamette River BiOp), initiated

in 2011 (with funding projected until at least 2020). We have been assisted by Dr. Eric Billman, a postdoctoral research associate (2011 – 2014; replaced by Dr. Karen Cogliati summer 2014), two graduate students (Julia Unrein, MSc completed December 2014; Kate Self, MSc graduation 2018), two part-time research assistants and two student work-study students. We now receive about $810,000 each year for this project, with significant leverage from OHRC, OSU and USGS in-kind support. This project aims to determine the rearing conditions that produce differences between wild and hatchery fish, and how to manage those differences to meet fishery and conservation needs. Our primary task is to provide juvenile fish of specified qualities, to research collaborators that include the ODFW, the USGS, the USACE and others, to be used in their field studies required by the NMFS Willamette Biological Opinion (BiOp). Those fish must emulate wild fish as closely as possible in terms of genetic origin, size, growth history, morphology, physiology and behavior. They are used by our research collaborators in tagging and telemetry studies of juvenile fish through reservoirs, through dams and fishways and down the Willamette River to Willamette Falls. We provide thousands of such fish, at different times of the year, to specifications from our collaborators. In order to produce those fish we are conducting extensive studies at the OHRC and the Fish Genetics and Performance Laboratory in Corvallis to determine the effects of genetic origin, diet, density, rearing substrate, rearing conditions and handling on the final performance of those fish in the Willamette River. We have been successful with this project in providing thousands of fish that perform almost the same as wild conspecifics, in contrast to conventional hatchery fish, for the studies in which they have been used. We have presented our results in Progress Reports each year. We have also given oral presentations on this project to ODFW, OSU, Oregon AFS, and other regional, national and international meetings. Our results from this and the steelhead wild surrogate project have implications and potential applications for ODFW and other management agencies. Our results inform management personnel on the practices and procedures to follow that can minimize (or maximize) the phenotypic and behavioral differences between wild fish and those produced in their hatcheries.

(4) Surrogates for wild Steelhead (Mission Goals 1.b., 2.a.2., 2.b., 2.d.)

This project, also funded by the US Army Corps of Engineers ($187,000 annually), was initiated in 2013. Results from this project served as the basis for a Master's thesis defended by Oregon State University graduate student Kate Self[6]. This project is analogous to the Chinook salmon wild surrogate project, and was requested by the Corps as result of our success with Chinook salmon. The objectives, procedures and evaluation are the same as for the Chinook project. As with the Chinook wild surrogate project, progress on this project is very well received by the Corps and other collaborators. The wild Chinook and steelhead surrogate research projects are both highly informative and potentially directly applicable to ODFW hatchery operations. Results from the wild surrogate project have lead to a series of Operational Research Projects at the OHRC designed to test the applicability of those findings to hatchery operations.

(6) Domestication selection (Mission Goals 1.a, 1.b., 2.d.)

This project is conducted by Dr. Michael Blouin, his postdoctoral research assistants and their laboratory collaborators. The project is a continuation of early work by Dr. Blouin at the OHRC, carried out as part of his long-term study of the factors producing lifetime differences in reproductive fitness of hatchery and wild salmon and steelhead. This project is another part of

[6] https://ir.library.oregonstate.edu/downloads/wm117t87d

the OHRC Research Plan (details elsewhere in this Report). Dr. Blouin's lab has a continuing series of publications from this work. Funding for this project originally came to Dr. Blouin from the BPA, with some in-kind support provided by OHRC personnel and facilities. This research is of primary concern to many people in the Pacific Northwest, as Dr. Blouin's earlier research is the basis for ongoing concerns about negative genetic effects of hatchery steelhead on wild counterparts. This project is the latest in a series of tests of specific predictions about the mechanisms causing reduced fitness of hatchery fish, and how one might change hatchery rearing conditions to make hatchery fish more like wild fish. In previous work at the OHRC his lab showed that raising fish at reduced densities did *not* reduce the opportunity for selection on size at release. This result failed to support a hypothesis that raising fish at high density exacerbates differences among families in size at release (of interest because size predicts survival after release). The lab has subsequently attempted to manipulate other aspects of hatchery rearing, such as feeding method, feed composition, and how water flows in tanks, in order to find conditions that would reduce the selection pressures. That work is either still under way or needs to be repeated before strong conclusions can be made. Blouin's lab has also been testing hypotheses about specific behavioral traits that may be favored under hatchery conditions. They are currently testing the hypothesis that hatcheries select for excessively bold behaviors. To date they have found evidence that families scored as more dominant performed better than those that scored as less dominant. In contrast, they have two years of data that fail to show a correlation between family preference for position in the water column and the growth rate of those families. This hypothesis was interesting because bolder fish tend to stay higher in the water column, which may give them improved access to food. Current experiments are replicating the water-column preference test, in addition to evaluating propensity to feed at the surface vs. near the bottom.

(7) Temperature and migration (Mission Goals 1.b., 1.c., 2.a.2., 2.d)

This project is being carried out in collaboration with Japanese colleagues, Professor Arimune Munakata, from Miyagi University in Sendai, Japan and his associates. He has come to the OHRC annually over a number of years to collaborate with Drs. Carl Schreck and David Noakes in this research. He has presented results of his research in both oral and published papers since he began this study. Funding for this research comes from Japanese awards to Professor Munakata, with some in kind support of facilities from the OHRC, and our project support from the US Army Corps of Engineers. This project was initiated because of interest in the factors that initiate the downstream movements of juvenile smolts of salmon and steelhead. The behavior and survival of salmon and steelhead smolts is of critical importance. The timing of downstream migration is obviously a major part of this phenomenon. Furthermore, there is the complexity that while some fish move downstream to the Pacific Ocean and complete their life cycle as anadromous steelhead, a significant but variable number of individual fish remain in freshwater as non-migratory rainbow trout. Those rainbow trout can have a significant effect on reproductive fitness of hatchery fish, and so it is important to learn what regulates this difference in migratory behavior of steelhead and rainbow trout. Professor Munakata's research has been remarkable because it shows that very small (perhaps less than 1^{o} C) changes in temperature can trigger downstream movement. Most remarkably, however, that downstream movement response is shown only by steelhead, rainbow trout show no such movement. Professor Munakata is now continuing his studies in Japan to determine what internal (physiological) mechanism produces this difference between steelhead and rainbow. That difference is part of a much larger concern,

because of the major differences in life history and management of rainbow and steelhead, as well as the influences on reproductive success than can result for hatchery fish. Dr. Munakata was here again in 2018 and carried out tests on the effects of temperature change on migration of Chinook salmon. He has presented those results at meetings in Japan and has two manuscripts in preparation for publication from this work. His current research is focused on genetic mechanisms in the brain that are responsible for initiating the movement of individual fish. The size of those fish, and their individual growth rates are also directly related to the probability that they will either migrate or remain in freshwater, and so this links closely with our studies of temperature and early growth in steelhead and Chinook salmon.

(8) Catch rates for hatchery steelhead produced with angler- vs. trap-caught broodstock (Mission Goals 1.c., 1.b., 1.c., 2.a.1., 2.a.2., 2.b., 2.c.)

This project was initiated in response to a request from the Alsea Sportsmen's Association, a local recreational angling group, together with other interested stakeholders. ODFW District Fish Biologist, John Spangler, took the lead and obtained R & E funding to provide for the necessary creel census for this project. Funding for analyses of genetic samples of parental broodstock was provided by the OHRC and ODFW, and facilities for the genetic work provided by State Fisheries Geneticist, Dr. Kathleen O'Malley, at the Hatfield Marine Science Center in Newport, Oregon. This project depended on extensive in kind and personnel support from ODFW, OHRC and OSU. Substantial efforts by collaborators on this project have helped to advertise the project, encourage angler participation and highlight the cooperative nature of this between ODFW and local anglers. The basic question for this project is whether the source and treatment of hatchery broodstock would affect the propensity of their offspring to be caught by anglers. Conventional hatchery broodstock programs collect brood fish from traps, using fish that have not been taken by anglers. In this study we test the hypothesis that the probability of a fish being caught by an angler is affected by the source (angler v. trap) of the parent fish. The prediction we are testing is that fish produced from conventional (trap caught) broodstock will be less likely to be caught by anglers than fish produced from broodstock that were caught by anglers. The question is simple and highly relevant to salmon and steelhead hatchery management. This study requires considerable cooperation, collaboration and coordination among anglers, ODFW hatchery managers and personnel, the OHRC personnel and researchers involved with the project. Collection of broodstock for this study occurred in 2015 and 2016, and their adult offspring returned and were sampled in the winters of 2017 and 2018. Ongoing genetic parentage analyses of the broodstock and their adult offspring are being conducted by Drs. Johnson and O'Malley to determine whether the offspring of angler-caught steelhead are more likely to be caught by anglers. Results from this study will be presented to ODFW managers and fisheries biologists, and published in international, peer-reviewed journals.

(9) Triploid steelhead (Mission Goals 1.c., 2.a.1., 2.a.2., 2.b., 2.d.)

This project is led by Dr. Marc Johnson (ODFW) of an earlier project initiated by requests from ODFW program managers. Our initial work on this project was the M. Sc. graduate thesis research by Eva Schemmel (recently completed her Ph.D. studies at Hawai'i). Eva tagged and tracked intact and surgically castrated hatchery adult steelhead in the Clackamas River. Her research showed that reproductively sterilized adult steelhead remained in the river, occupied the same locations as intact fish, and were caught by anglers at the same rate as intact (control) fish.

This immediately led us to investigate practical alternatives for producing reproductively sterile hatchery steelhead. Subsequent work on this project was supported by OHRC and ODFW funding, personnel and facilities. Of several options tested, we learned that using triploid fish was likely the best option. Ryan Couture, Joseph O'Neil and ODFW hatchery personnel worked to develop the detailed protocol to produce triploid steelhead and other salmonids in subsequent research at the OHRC. Triploid fish are reproductively sterile, and can be reared in large numbers using conventional production hatchery techniques. Ryan, Joseph and ODFW hatchery personnel tested the behavior of triploid fish in the experimental stream channels at the OHRC to confirm that they are reproductively sterile. The triploid nature of the fish is confirmed by analysis of blood samples at the ODFW Fish Health Laboratory at OSU. The techncique developed by Ryan Couture and Joseph O'Neil produces at least 98% sterile triploid fish and that technique has now been adopted by ODFW hatcheries as standard procedure. This project then moved to the production scale testing necessary to determine if these fish can be produced by ODFW hatcheries and stocked as smolts with Dr. Marc Johnson as the research lead. During 2015 and 2016, Dr. Johnson had extensive collaboration with the Oregon Coast Community College (Newport, Oregon) and the Oregon Coast Aquarium, to monitor growth and survival of diploid and triploid steelhead in salt water. Dr. Johnson has followed those marked fish (PIT tags) to estimate downstream movement, ocean survival and subsequent return rates as adults and angler harvest rates. This has been a multi-year project, involving collaboration and cooperation with many people. The results of this project are of major interest to ODFW program managers, fish biologists and hatchery personnel. If reproductively sterile hatchery fish can be stocked in selective watersheds to support recreational angling harvest then a major concern of hatchery – wild interactions will be resolved. The first returning fish from this Project (diploid and triploid adults) were captured in 2016, and Dr. Johnson is now analyzing data from those fish.

(9) Effect of Mate Choice on Fitness (Mission Goals 1.a., 1.b., 1.c., 2.a., 2.b.)

This project is identified in the OHRC Research Plan and is led by Dr. Michael Banks, with assistance from Dr. Heather Auld. The premise of their research is that mate choice decisions made by wild salmon and steelhead under natural settings may involve genetic information that, ultimately boosts their individual fitnesses. Accordingly, Drs. Banks and Auld have set about mining genetic pedigrees of naturally spawning Chinook and coho salmon to identify genetic marker combinations formed through parental contributions (i.e. mating pairs) that resulted in higher average fitness. This work require to high resolution screening of thousands of genetic markers in hundreds of fish, and has employed the resources of the OHRC, Oregon State University's Center for Genetic Resources for Biotechnology (CGRB) and the Hatfield Marine Science Center. In 2018, these researchers identified a suite of genetic markers that pair at unexpectedly high frequencies in successful wild salmon mating pairs, and now plan to implement genetic screening of hatchery salmon to be used for informed crosses during spawning. Subsequent efforts will compare the fitness (i.e. productivity) of these informed crosses with those of typical, random matings at one or more Oregon salmon hatcheries.

Impact of Research:

Reports and Publications

Results of our research are given in numerous oral presentations and publications, selected examples are listed below:

Auld, H.L. D.L.G. Noakes & M.A. Banks. 2019. Advancing mate choice studies in salmonids. *Reviews in Fish Biology and Fisheries*. https://link.springer.com/article/10.1007/s11160-019-09551-5

Cogliati, K. M., J. R. Unrein, W. M. Sealey, F. T. Barrows, O. Hakanson, R. Chitwood, D. L. G. Noakes, C. B. Schreck. Low-lipid starter diets at reduced ration can produce high quality wild-like Chinook Salmon. *North American Journal of Fisheries and Aquatic Sciences* (in press)

Cogliati KM, Herron CL, Noakes DLG, Schreck CB. 2019. Reduced stress response in juvenile Chinook Salmon reared with structure. *Aquaculture* 504:96-101.

Cogliati, K.M., J. R. Unrein, H. A. Stewart, C. B. Schreck, D. L. G. Noakes. 2018. Egg size and emergence timing affect morphology and behavior in juvenile Chinook Salmon, *Oncorhynchus tshawytscha*. *Ecology and Evolution*, 8(1): 778-789.

Cogliati, K. M., J. R. Unrein, C. B. Schreck, D. L. G. Noakes. Rearing environment affects spatial learning in juvenile Chinook Salmon. *Ethology* (in review)

Herron CL, Cogliati KM, Dolan B, Munakata A, Schreck CB. 2018. Stress up-regulates oxidative burst in juvenile Chinook salmon leukocytes. *Fish & Shellfish Immunology* 80:655-659.

Johnson MA, Friesen TA, VanDoornik DM, Teel DJ, Myers JM. 2018. Genetic influence from hatchery stocks on upper Willamette River steelhead Oncorhynchus mykiss. ODFW Information Report, available at https://odfw.forestry.oregonstate.edu/willamettesalmonidrme/sites/default/files/info_report_2018-03_uwr_steelhead.pdf

Johnson MA, Noakes DLG, Friesen TA, Dittman AH, Couture RB, Schreck CB, Banner C, May D, Quinn TP. Growth, survivorship, and juvenile physiology of triploid steelhead (*Oncorhynchus mykiss*) (in review)

Marsden, J. E., A. M. Muir, C. C. Krueger, D. L. G. Noakes. Chapter X. Terminology issues in lake charr early development. In: A. M. Muir & C. C. Krueger (editors), Biology and management of lake charr, *Salvelinus namaycush*. *Fish & Fisheries*, Springer Academic (in review).

Munakata, A., E. Ogihara, C. B. Schreck, D. L. G. Noakes. 2017. Effects of short term acclimation in cool and warm water and influent water temperatures on temperature

selection behavior in juvenile steelhead trout, *Oncorhynchus mykiss*. *Aquaculture 467*: 219 - 224.

Noakes, D. L. G. Foreword. In: M. F. Docker (editor), *Lampreys, Biology and Management*. Volume 2. Fish & Fisheries, Springer.

Pollock, M. M., M. Kamran, A. H. Dittman, M. A. Johnson, D. L. G. Noakes. Within-river straying: Sex and size influence recovery location of hatchery Chinook salmon (*Oncorhynchus tshawytscha*). *Canadian Journal of Fisheries & Aquatic Sciences* (in press).

Putman, N.F., M. M. Scanlan, A. M. Pollock, J. P. O'Neil, R. B. Couture, J. S. Stoner, T. P. Quinn, K. J. Lohmann, D. L. G. Noakes. 2018. Geomagnetic field influences upward movement of young Chinook salmon emerging from nests. *Biology Letters 14*(2): 20170752

Scanlan, M., N. F. Putman, A. M. Pollock, D. L. G. Noakes. 2018. Magnetic map in nonanadromous Atlantic salmon. *Proceedings of the National Academy of Sciences* 115 (43): 10995 – 10999.

Self, K. E., C. B. Schreck, K. M. Cogliati, E. J. Billman, D. L. G. Noakes. 2018. Egg size and growth in steelhead *Oncorhynchus mykiss*. Journal of Fish Biology 93(3): 465 – 468.

Self, K. E., C. B. Schreck, K. M. Cogliati, E. J. Billman, D. L. G. Noakes. 2018. The effect of rearing structures on behaviour and movement of juvenile steelhead *Oncorhynchus mykiss.* Journal of Fish Biology 93(3): 449 – 454.

Stewart, H.A., K. M. Cogliati, E. J. Billman, R. Chitwood, J. R. Unrein, D. L. G. Noakes, C. B. Schreck. 2017. Effects of transportation timing on osmoregulation and survival in yearling hatchery Chinook salmon (*Oncorhynchus tshawytscha*). Journal of Applied Aquaculture *29*(3-4): 277-290.

Thompson NF, Blouin MS. 2016. Family dominance level measured during the fry stage weakly influences family length at smolting in hatchery reared steelhead (*Oncorhynchus mykiss*). *Transactions of the American Fisheries Society* 145: 1282-1289.

Thompson, NF and MS Blouin 2015 The effects of high rearing density on the potential for domestication selection in hatchery culture of steelhead (*Oncorhynchus mykiss*). *Canadian Journal of Fisheries and Aquatic Sciences.* 72:1-6.

Thompson, NF, B Clemens, L Ketchum, P Simpson, R Reagan and MS Blouin. 2018. Family influence on length at release and size-biased survival post release in hatchery-reared steelhead: a mechanism to explain how domestication occurs. *Aquaculture* 491:135-146

Unrein, J.R., E. J. Billman, K. M. Cogliati, R. Chitwood, D. L. G. Noakes, C. B. Schreck. 2018. Vertical self-sorting behavior in juvenile Chinook salmon (*Oncorhynchus tshawytscha*): evidence for family differences and variation in growth and morphology. *Environmental Biology of Fishes*, 101(2): 341-353.

Papers Presented at Research Conferences

2018

Cogliati KM, Schreck CB, Noakes DLG. The Wild Fish Surrogate Project. Feeding and Nutrition Workshop at the Oregon Hatchery Research Center, Alsea, OR.

Cogliati KM, Self KE, Noakes DLG. Oregon Hatchery Research Center: Recent findings from the Wild Fishes Surrogate Project. Mid-Valley NW Steelheaders, Albany, OR.

Cogliati KM, Noakes DLG, Schreck CB, Sharpe CS. The wild fish surrogate program: producing fish for research including parental based tagging studies. Willamette Fisheries Science Review, Corvallis, OR.

Cogliati KM, Schreck CB, Noakes DLG. The shape of things that go: can early life history traits predict migration timing? International Congress on the Biology of Fish, Calgary, AB.

Cogliati KM, Unrein JR, Schreck CB, Noakes DLG. The effect of rearing environment on spatial learning ability in juvenile Chinook Salmon. Oregon Chapter American Fisheries Society, Eugene, OR.

Cogliati KM, Self KE, Scanlan MM, Schreck CB, Noakes DLG. Sticking together? Motivation to be near conspecifics for juvenile Chinook salmon reared in three different environments. Ecological and Evolutionary Ethology of Fishes, Montreal, QC.

Herron CL, Cogliati KM, Noakes DLG, Schreck CB. Juvenile Chinook Salmon reared with tank structure have decreased plasma cortisol levels. Oregon Chapter American Fisheries Society, Eugene, OR.

Johnson, M. A. Friesen TA, Dittman AH, Olmsted PM, Noakes DLG, Couture RB, Schreck C, Quinn TP. 2018. Juvenile physiology, performance and migration behavior of triploid summer steelhead. PSMFC hosted Steelhead Managers Meeting, Walla Walla, WA. 22 March 2018.

Noakes, D. L. G. 2018. The secret life of salmon. Willamette Fisheries Science Review, US ACOE, OSU, February 2018.

Noakes, D. L. G. 2018. Olfactory Imprinting Research Project, OHRC Advisory Board, 26 March 2018.

Noakes, D. L. G. 2018. Research Update and Olfactory Imprinting Research Report, OHRC Advisory Board, 3 April 2018.

Noakes, D. L. G. 2018. Chinook salmon research. Port Orford, Oregon, 18 May 2018.

Noakes, D. L. G. 2018. The life and hard times of salmon, Part 3. The Ocean. Salmon Ocean Ecology Meeting, Newport, Oregon,

Noakes, D. L. G. 2018. Predicting ocean navigation by salmon. Salmon Ocean Ecology Meeting, February 2018.

OHRC Updates/Future Projects.

Johnson, M. A. 2018 Broodstock Integration: Why and How. ODFW Hatchery Managers Meeting, Big K Ranch, Elkton, OR. 20 September 2018.

Noakes, D. L. G. 2018. ODFW Hatchery Managers, Big K Ranch, 8 August 2018.

Noakes, D. L. G. Updates and Olfactory Imprinting Research Project Report. OHRC Advisory Board Meeting. 18 September 2018.

Noakes, D. L. G. OHRC Operational Research. OHRC Advisory Board Meeting, 18 September 2018.

Noakes, D. L. G. Salmon, Orientation, Migration and Homing. Port Orford, Oregon, 18 October 2018.

Noakes, D. L. G. 2018. Movement ecology and diversity of Pacific salmon. BioMove Research Conference, Potsdam, Germany, September 2018.

Noakes, D. L. G. Olfactory Imprinting Research Project Report, OHRC Research Project Meeting, 9 October 2018.

Noakes, D. L. G. & J. O'Neil. OHRC Operational Research, OHRC Advisory Board Meeting, 2018. 4 December 2018.

Noakes, D. L. G. 2018. Nearly perfect fishes. Within Our Reach. Willamette River Review Meeting, Salem, Oregon. 13 December 2018.

Pollock, A.M., M. Kamran, A. Dittman, M. Johnson, D.L.G. Noakes. When Chinook go astray: analyzing straying trends in Elk River hatchery Chinook salmon. Oral presentation at Research Advances in Fisheries and Wildlife Ecology symposium, 2018 April 27; Corvallis, OR.

Pollock, A.M., M. Kamran, A. Dittman, M. Johnson, D.L.G. Noakes. Analyzing straying trends in Elk River hatchery Chinook salmon. Oral presentation at the Oregon Hatchery Research Center for students from Nitobe University (Japan), 2018 March 20; Alsea, OR.

Pollock, A.M., M. Kamran, A. Dittman, M. Johnson, D.L.G. Noakes. When Chinook go astray: analyzing straying trends in Elk River hatchery Chinook salmon. Oral presentation at Oregon Chapter of the American Fisheries Society Annual Meeting, 2018 March 16; Eugene, OR.

Schreck CB, Kent M, Colvin M, DeWeber T, Sanders J, Janik D, Peterson J, Cogliati KM, Herron CL, Noakes DLG. Stress is moderated by environmental structure in juvenile and associated with parasites in adult Chinook Salmon during upstream migration. International Congress on the Biology of Fish, Calgary, AB.

Scanlan, M., Nathan Putman, Amanda Pollock, Joseph O'Neil, and David L.G. Noakes. 2018. Anadromous salmon display maladaptive orientation to southern hemisphere magnetic fields. Oregon Chapter of American Fisheries Society annual meeting. March 2018.

Scanlan, M., Nathan Putman, Amanda Pollock, Ryan B. Couture, Joseph O'Neil and David L.G. Noakes 2018. Geomagnetic Orientation Throughout the salmon life cycle. Presented to visiting students and faculty from Hokkaido University, Japan. Oregon Hatchery Research Center, March 16, 2018.

Scanlan, M. M; Putman, Nathan F; Pollock, Amanda M; Noakes, David L. G. 2018.Where do landlocked Atlantic salmon think they are? A magnetic map sense in a non-anadromous population. Biennial Ecological and Evolutionary Ethology of Fishes Meeting. June 2018. Montreal, Quebec.

Schreck CB, Munakata A, Yada T, Cogliati KM, Noakes DLG. Temperature changes may affect migration differently across Chinook Salmon phenotypes. Oregon Chapter American Fisheries

OHRC research attracts attention, collaborators and joint research proposals. The impact of the Center's research can be estimated by conventional methods – such as the number and distribution of published material. However, the ongoing OHRC Research Plan Projects (Drs. Michael Banks, Mike Blouin, David Noakes) are also regularly cited in news articles, popular media, and online outlets.

Sample searches on the Internet further reveal the reach of our research:

https://www.google.com/?gws_rd=ssl#q=blouin+salmon+fitness

https://www.google.com/?gws_rd=ssl#q=banks+salmon+mate+choice

https://www.google.com/?gws_rd=ssl#q=noakes+olfactory+salmon

Research Workshops

We continue our series of Research Workshops at the OHRC on a range of topics to meet the OHRC Mission (Diet and Growth). In addition, we participate actively in local, regional, national and international scientific meetings where we present the results of our research. We organized and hosted the Willamette Fisheries Science Review at Oregon State University in 2018, and served on the organizing and steering committee for the international biennial conference on Ecology, Ethology and Evolution of Fishes (Concordia University, Montreal, Canada).

OHRC Mission Goal 3: Education and Outreach

Joseph O'Neil (ODFW – retired in December 2018) and Jen Krajcik (ODFW) continued their activities at the OHRC and during visits to a number of schools in Lincoln County during 2018 as the lead people responsible the Education and Outreach activities at the OHRC. They were key people in the OCAMP Science Education Project, and they continue as active members of the Oregon Coast STEM project. They are responsible for organizing and hosting school visits and school tours at the OHRC as well as taking presentations to schools and meetings away from the OHRC. We have made presentations and hosted visits of more than 1,000 elementary and secondary school students in this program. In addition, we travel to schools throughout Lincoln, Benton and Tillamook counties to provide organized science exercises to classes from kindergarten to Grade 12 students. We also provide science classes and science exercises to meetings of Scouts and other service groups.

David Noakes continues as one of the Co-PI personnel for the Oregon Coast STEM (budget details listed elsewhere). He provides invited seminars, leads science colloquia and makes school visits to judge science fairs and to advise students at all levels. He is also responsible for teaching duties in the Fisheries and Wildlife Department at OSU, including a postgraduate class in Fish Ecology & Conservation. He continues to give invited lectures and seminars at OSU on Scientific Publishing, Environmental Physiology of Fishes and on salmon biology and conservation. He regularly supervises postgraduate students who conduct their research at the OHRC, and serves on the Advisory Committees for other postgraduate students at OSU. His activities in the Oregon Coast STEM project include visits and presentations to classrooms, advising on student projects and coordinating school visits and presentations by visiting scientists. He also presents invited lectures on OHRC research, scientific editing and publishing at regional, national and international meetings.

Every year a number of postgraduate students, research associates and postdoctoral research scholars conduct part or all of their research at the OHRC, with support in kind from our personnel and facilities. Their research topics include subjects as diverse as studies of the impact of dams and fish passage on steelhead in the Umpqua River, responses of juvenile salmon to avian predators, domestic selection on wild and hatchery fish, experimental production of hatchery salmon and steelhead to behave and perform as wild fish, olfactory imprinting in salmon and steelhead and the use of geomagnetic cues for navigation by juvenile and adult salmon and steelhead.