Oregon Hatchery Research Center
2017 Annual Report

To:

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

By:

Oregon Hatchery Research Center Board

April 6, 2018

Executive Summary

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

- Positive work towards an OHRC Communications Plan;
- Research activities conducted in 2017 by the OHRC and collaborators in relationship to the mission and goals for 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 other research conducted at the OHRC;

- Activities of the Board in 2017 and 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 Oregon Hatchery Research Center and any recommendations regarding current hatchery management practices based on the research projects.

This report constitutes the fifth 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 Board to date, describe the funding and implementation of the Research Plan for the OHRC adopted by the Board in 2014, report the status of a new ODFW fish geneticist position, and present summary research findings and recommendations from studies conducted at the OHRC in 2017.

2017 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 board members as of December 31, 2017 and their designated terms. The Board is currently led by Cam Parry as the Board chair and Scott Starkey and Lindsay Ball as the vice-chairs.

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	07/01/20
Wild Fish	Brad Halverson	07/01/19

Wild Fish	Kyle Smith	07/01/21
Sport Angler	Jack Smith	07/01/19
Sport Angler	Lindsay Ball	07/01/21
Agriculture	Vacant	07/01/20
Ports	Chuck Pavlik	07/01/20
Forestry	Scott Starkey	07/01/19
Independent Science	Steve Jacobs	07/01/21
Habitat Restoration	Cam Perry	07/01/19
Tribes	Maureen Hess	07/01/20
Federal	Charlene Hurst	Indefinite, non-voting
OSU	Carl Schreck	Indefinite, non-voting
ODFW	Bruce McIntosh	Indefinite, non-voting

OHRC Board Terms Expiring and Resignations:

Four OHRC Board position terms ended July 1, 2017. These positions represented the Oregon Salmon Commission, wild fish advocacy groups, sport anglers and independent science. All four board members (Dwight Collins, Kyle Smith, Lindsay Ball and Steve Jacobs) agreed to serve another four-year term and were re-appointed by ODFW Director Melcher.

Efforts continued to find candidates for the agriculture and Columbia River gillnetters positions.

OHRC Board Activities in 2017:

Overview

The OHRC Board oversaw the implementation of the OHRC Research plan throughout 2017 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 at the OHRC on March 7, 2017. The Board received an update on progress implementing the OHRC Research Plan. The Board reviewed and approved the 2016 OHRC Annual Report. The Board was given updates on several legislative bills being worked on in the 2017 Legislative Session that related to the OHRC's research fund and appointing board members, as well as issues related to stream restoration. The Board received a presentation on the recently completed Federal ESA Recovery Plan for Oregon Coastal Coho Salmon. A research proposal was also presented to the Board for research to potentially be conducted at the OHRC. The Board reviewed the previous process for considering research proposals and approved that process to be used for future proposals. See the following link for board meeting minutes (http://www.dfw.state.or.us/fish/OHRC/minutes.asp).

The OHRC Board met again at the OHRC on June 6, 2017. The Board received updates from various members on activities related to the OHRC that they were involved with since the last meeting. ODFW provided an update on negotiations with the US Army Corps of Engineers on funding the Willamette Project hatcheries and trout production. An update was given to the Board on implementation of the OHRC Research Plan, as well as the status of the OHRC Research Fund. The Board received a presentation from the Oregon Forest Resources Institute on the timber industry's efforts under the

Oregon Plan for Salmon and Watersheds. A research proposal was presented to the Board for a potential project to be conducted at the OHRC. See the following link for Board agenda and minutes (http://www.dfw.state.or.us/fish/OHRC/minutes.asp).

Due to scheduling conflicts with board members, the Board next met at the OHRC on November 14, 2017. Since this meeting was postponed two months, the Board agreed to cancel the planned December meeting, so this was the last meeting of 2017. Board members gave updates on education efforts in local schools and issues of interest to them. A high school student presented his idea for a senior project to create a promotional video on the OHRC for use in schools. The Board encouraged him to complete the video and provided him with some ideas. A presentation was given to the Board on the Kids Fish Free program that is underway in Coos County – providing free fishing rods and reels to children. The new Statewide Fisheries Geneticist (Kathleen O'Malley) was introduced to the Board and gave a presentation on her background and what knds of work she saw this new position doing. The Board also discussed ideas for their work plan for 2018. There was consensus that more work was needed on sharing what the OHRC does with the general public. It was decided that the new chair of the Board would lead this effort – election of chair and vice chair was tabled until the February 2018 meeting. See the following link for board agenda and minutes (http://www.dfw.state.or.us/fish/OHRC/minutes.asp).

OHRC Board Focus in 2018:

Based on discussions during the November meeting, the Board will be focusing on telling the story of the work being done at the OHRC and how it has been used in Oregon and elsewhere. In addition, the Board will continue to advise ODFW, OSU and the OHRC Director on priorities and research implementation at the OHRC.

OHRC Activity Report 2017:

Overview

Our most important research activity was the implementation and initiation of the OHRC Research Plan, consisting of three (3) Research Projects. Detailed information on the Research Plan (approved in 2014) and the individual Research Projects is provided in the OHRC Research Plan. Funding for the Research Plan was confirmed effective 1 July 2015, subject to formal agreements between ODFW and Oregon State University. Drs. Mike Garvin, Maryam Kamran and Heather Auld were hired for the three research projects. Each of these projects addresses major interests identified in the OHRC Research Plan, which can briefly be characterized as investigations to determine: 1) the mechanisms of domestication associated with hatchery rearing 2) genetic bases to mate choice in salmon and associated effects on reproductive fitness and 3) means to improve olfactory imprinting that may be used to reduce stray rates in hatchery salmon.

The research topic called for in the OHRC Research Plan and headed by Dr. Michael Blouin (effects of hatchery rearing, or domestication selection) continued as planned, with genetic analyses of hatchery fish reared at different densities looking for genes under selection. Although differential gene expression was observed among experimental steelhead, rearing density was not conclusively identified as a mechanism for domestication selection in the hatchery. Dr. Blouin's group has initiated experiments to test a second hypothesis related to growth rates, which may ultimately explain among-family differences in survival and fitness. Analyses of data from that work are currently underway.

The Research Project led by Dr. Michael Banks (genetics bases of mate choice) progressed as planned during 2017. During this year, Drs. Bank and Auld analyzed data from existing genetic pedigrees (coho, Chinook and steelhead) and supplemented these datasets with higher-resolution genetic information gained through next-generation sequencing techniques. This approach has allowed them to identify candidate genes associated with high fitness mate pairs that formed during natural spawning. Dr. Auld has also worked with samples provided by Dr. Noakes from an experiment that was previously carried out to examine patterns of mate selection by steelhead in the stream channels at the OHRC. However, those analyses were complicated by an apparently low parent-offspring assignment rate that could not be readily explained, but is under further investigation.

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 Sizes rivers in southern Oregon to determine the chemical nature of the river water at the time 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 first year of testing behavioral responses of young Chinook salmon to selected test chemicals took place at the OHRC. This group also measured the olfactory receptor responses of salmon to selected chemicals in the NOAA (NWFSC 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 schedules, timelines and research activities for all three Research Projects are provided through project descriptions and decision charts in the OHRC Research Plan. Initial reports to the OHRC Advisory Board on each of these three projects occurred during the regularly scheduled OHRC Board meetings of 2017. In addition, participants of these projects met during bimonthly meetings to discuss preliminary results, approaches and challenges, and to coordinate activities. The outcome of those meetings were presented to the OHRC Board during their regular meetings.

ODFW worked closely with OSU to develop a jointly-managed State Fisheries Geneticist position, partially funded by the 2015 Oregon Legislature. In 2017, the search committee (which included Drs. Noakes and Schreck) made their recommendations and Dr. Kathleen O'Malley was hired to serve in this position. Dr. O'Malley is an alum of Oregon State University, has extensive experience and publications related to the genetics of salmon and other Oregon fishes, and will work closely with the OHRC to further the Center's objectives and mission.

The OHRC continued to address its mission in 2017 through support and involvement with research aimed to: investigate whether vulnerability to angling represents a heritable "trait" in hatchery steelhead (a.k.a. the "Alsea Biter Study"); investigate the performance of sterile triploid steelhead; investigate the role of geomagnetic cues during navigation by salmon and steelhead; investigate methods to develop "wild-like" phenotypes in hatchery salmon and steelhead (a.k.a. the "Wild Surrogate Project") for research applications. These activities and more are described in detail at: http://www.dfw.state.or.us/fish/OHRC/news.asp. Earlier reports available through the OHRC website further reveal progress of OHRC research activities.

OHRC Mission

The first goal of the OHRC 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 questions with the following research projects in 2017:

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. Outplanting and angler harvest of Alsea River steelhead – OHRC, ODFW
1.c. Homing and straying in Chinook and steelhead – Noakes, Blouin, 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 questions with the following research projects in 2017:

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 Sportsmens 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

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. We continue to host student interns from local Community Colleges for technical training and research experience. For example, we have developed a research project, in collaboration with colleagues from Mt. Hood Community College to investigate the feasibility of enhancing diets of hatchery fish with naturally occurring insect prey.
    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. 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.
    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 Oregonians 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. We give regular presentations to various stakeholders, community organizations and local residents in Port Orford on our olfactory imprinting study at the ODFW Elk River Hatchery.
    h. Share research results through both publications and presentations on the local, state and international level. OHRC researchers regularly publish and present results from their work. These activities are presented in detail through Appendix 1 of this report.

The OHRC is a clearinghouse for, and helps facilitate, research in Oregon related to 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, during periodic presentations on the progress of research at the OHRC. Administrators and

managers review these results and their applicability to hatchery programs and fish management, and direct changes to be made where applicable.

The OHRC continued its activity in Education and Outreach in 2017 through Research Workshops focused on both applied and basic Research at the OHRC. We maintained active educational programs at every level from kindergarten to post graduate university students. The OHRC hosted school visits, participated in teacher training, school visits and coordinated professional activities with students and teachers. Center staff provided educational activities and opportunities at every level from kindergarten to postgraduate university students.

OHRC personnel participated in numerous outreach activities with the local community, ODFW staff, and colleagues from universities and research organizations across Oregon, throughout the USA, Canada, China, Norway and Japan. The Center hosted visiting researchers, university and school groups, as well as making visits and invited presentations to services clubs, angler organizations and to educational institutions. OHRC staff and researchers participated in local, regional, national and international research meetings where we presented results of OHRC educational and research activities.

The OHRC hosted visits from colleagues from across Oregon, the USA, Canada, Japan, and China (listed above), and in some cases these led to funding applications for new projects that involve collaborators interested to perform joint research that would utilize the OHRC's unique facilities. The OHRC remains active in publishing the results of our research in a number of international scientific journals and printed books as well as electronic 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

We brought in about $1.5 million in research activity to the OHRC in 2017, 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 2017 (see details below). 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: Olfactory Imprinting, Temperature and Sex Change, Wild Broodstock (Alsea angling study), Steelhead Smolt Survival, and Otolith Marking. We also received specific funding for individual projects: US Army Corps of Engineers (Chinook and steelhead surrogates), Noakes & Schreck ($768,000 year. We also received additional funding from ODFW, through Legislative allocations, to support the three Research Projects of the Research Plan ($600,000 for the 2015/2017 biennium; details provided below). 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. We also supported a number of our graduate students with individual awards to them as fellowships and scholarships. Many of our 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 have 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 7 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 of each year, and a Fall Festival in November. On those occasions the Center is open to the public and hosts 200 – 300 people, including many families – for the event.

Management Recommendations in 2017 Based on OHRC Research Findings

Research conducted through the OHRC in 2017 generated useful information for effective hatchery management in Oregon. While some results only identified areas for further research, OHRC staff and researchers presented many useful findings to ODFW hatchery managers and biologists for their consideration.

In particular, experiments conducted through the OHRC suggested better olfactory imprinting – a necessary prerequisite to the renowned homing behavior of salmon – by salmon incubated in river water, relative to fish incubated in well water (per common practice). This finding was applied in several Oregon salmon hatcheries, including the Elk River and McKenzie hatcheries, where the effects of river water incubation on stray rates will be monitored during future adult return years.

Appendix 1: Detailed Activity Reports for the OHRC

OHRC Mission Goals 1 and 2: Research Projects

Research Projects at the OHRC are reviewed according with the Center's 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, 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 to annual ODFW Meetings (hatchery managers and regional biologists in alternate years).

Individual Research Projects
During 2017, OHRC researchers and staff engaged in many research projects. A selection of these projects are listed below:

(1) Olfactory imprinting (Mission Goals 1.c., 2.d)
OHRC research on this topic addresses a high priority request from ODFW to provide recommendations for their management of hatchery salmon and steelhead. This project began in 2012, with funding provided from the OHRC – OSU operating budget, and in kind support provided by ODFW hatcheries, NOAA (NWFSC), and OSU. This project expanded in 2017 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), as well as several 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. Her thesis defense and graduation are scheduled to be complete in 2018. This research team has 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 2017 at the Oregon Chapter of the American Fisheries Society, the International Charr Symposium, and the biennial conference on Ecology, Ethology and Evolution of Fishes. This research team has shown that both Chinook salmon and steelhead imprint on the water in which they are incubated, from fertilization to swim up stage. The 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. Our results have resulted in significant re-evaluation of ODFW hatchery practices for the use of water during incubation. Our colleagues in Vermont have tested our predictions with Atlantic salmon (*Salmo salar*) and have found that fish incubated in river water return at four times the number incubated in well water (their standard procedure) – a result that is likely to change their hatchery management practices. We continued our international collaboration on this project with colleagues from the USA, Norway, Sweden, Argentina, Newfoundland (Canada) and Japan. We are now studying the detailed changes in the brains of Chinook salmon and steelhead during their responses to olfactory imprinting cues and geomagnetic orientation. We will continue this research as one of the three Research Projects in the OHRC Research Plan (details given in that section of this report). The critical step in this research will 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 production smolts.

The homing/straying of the returning adults will determine whether ODFW (and probably other agencies) changes their 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 major papers has been published from this research and more are in progress (Putman et al.). Results from that work have been presented at a number of 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 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.

(3) Chinook wild surrogates (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 expected June 2018), two part-time research assistants and two student work-study students. We now receive about $580,000 each year for this project, with significant leverage from OHRC, OSU and USGS in-kind support. The first of a series of papers from this study were published in 2015 (Billman et al., Putman et al.) and a series of others are in various stages of publication. This project, together with the steelhead wild surrogate project, are examples of studies to determine what rearing mechanisms 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 from the ODFW, the Corps and others, to be used in their field studies required by the Willamette 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 tracking 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. Thus far the numbers of our wild surrogate fish that have been released in the wild have been deliberately kept limited, to avoid any potential genetic or ecological interactions with wild fish.

(4) Steelhead wild surrogates (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. A postgraduate student, Kate Self, is working on this for her M. Sc. degree, supported by Corps funding (expected completion Spring 2017). This project is exactly comparable to the Chinook wild surrogate project, and was requested by the Corps as result of our success with the 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.

(5) Temperature and sex change (Mission Goals 1.a., 1.b., 2.d.)
This project was initiated in response to concerns brought to ODFW and OSU about possible effects of climate change on wild salmon and steelhead, and the potential for hatchery rearing effects at ODFW production hatcheries. The first manuscript from this project has been submitted for publication (Cole et al.), and two others are in preparation. We have presented our results at a number of national and international scientific meetings here in Oregon, Hawai'i, Scotland and Canada. Our results are of considerable significance to hatchery managers, since we found no evidence to suggest that the range of temperatures used to rear fish are likely to produce sex change. Wild fish are also not likely to change sex as a result of the projected temperature changes forecast by climate models. However, it is clear that elevated water temperatures during incubation can change the rate of sexual development in steelhead, especially in hatchery fish. Our results are important because of our conclusions, and because they resolve some uncertainty about the potential impacts of climate or habitat changes. There might also be concerns about the consequences of rearing steelhead at elevated temperatures in hatcheries, for otolith marking, or to regulate production schedules.

(6) Domestication selection (Mission Goals 1.a, 1.b., 2.d.)
This project is conducted by Dr. Michael Blouin, his postdoctoral research assistants, Drs. Neil Thompson and Mike Garvin, 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 the OHRC Research Plan (details elsewhere in this Report). Drs. Neil Thompson, Mike Garvin and Mike Blouin have a continuing series of publications from this work. Funding for this project comes to Dr. Blouin from the BPA, with some in kind 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 by Dr. Blouin from his hypotheses for the mechanisms causing the reduced fitness of hatchery fish. He has reared genetically identified fish from both hatchery and wild parents, under a number of different density conditions. His prediction was that hatchery fish would do well at high rearing densities (= hatchery conditions) while wild fish would do well at low rearing densities (= wild conditions). The results from this study did not confirm his predictions, but suggested another hypothesis that success in the hatchery was dependent on reaching a critical size at smoltification. This hypothesis is now being tested (2016 – 2017) at the OHRC.

(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, since we have shown in other projects that only about 40% of smolts survive to reach the Pacific Ocean (Romer et al.). 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.

(8) Wild 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 Sportsmens Association, a local recreational angling group, together with other interested stakeholders. Derek Wilson, ODFW Fish Biologist in Newport has taken the lead and obtained R & E funding to provide for the necessary initial 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 Dr. Michael Banks at HMSC. This project depends on extensive in kind and personnel support from ODFW, OHRC and OSU. There has also been a lot of effort by a number of collaborators on this project to advertise the project, to encourage angler participation and to highlight the cooperative nature of this between ODFW and local anglers. This project has also involved very extensive outreach with the local anglers and other stakeholders, numerous public presentations and continued close cooperation with the general public. This project is of much broader interest to ODFW hatchery personnel and program managers. The basic question in this project is whether the source and treatment of hatchery broodstock will change the success rate of anglers on returning fish. Conventional broodstock programs take their fish from traps, using fish that have not been taken by anglers. The hypothesis we are testing is that the probability of

being caught by anglers is affected by the source and handling 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 will fish produced from broodstock fish that were caught by anglers. The question is simple, obvious and very significant. The test requires very considerable cooperation, collaboration and coordination among the anglers, the ODFW hatchery managers and personnel, the OHRC personnel and the OSU scientists in the project. We now have all the elements of the project in place, and we are awaiting the returns of the first fish from the two sources of adult broodstock (2017). The project will have to extend over at least one life cycle of the fish, to measure angler harvest of the returning fish from the two sources of broodstock. The results of this project will be of considerable interest and importance to anglers, ODFW fish hatchery managers, ODFW fish biologists and ODFW program managers, as well as the research scientists. If we find the predicted difference in angler harvest there will undoubtedly have to be significant changes in broodstock management practices and procedures. If there is no difference in angler harvest of returning steelhead, then angler groups and other interest groups, as well as research scientists, will be assured broodstock collection is not responsible for the level of contribution of these fish to the fishery. This will resolve a long-standing concern about hatchery management, and it will also demonstrate a contrast in the situation between the original example of angler catch of bass in Illinois, and angler catch of steelhead in Oregon. This project has been widely discussed in the local and regional communities, and has been the subject of feature stories in The Oregonian and has been presented by us a number of times to meetings of the OHRC Advisory Committee and other groups. The project was initiated with wild broodstock at the Alsea North Fork Hatchery during this brood year (2014 – 2015). Initial release of smolts began in 2016, following standard hatchery practices. A creel survey, funded by ODFW Restoration and Enhancement Program, was used to collect samples of harvested fish from anglers, while trap-caught steelhead were sampled by Alsea Hatchery staff. Genetic parentage analyses will be used to assign trap- and angler-caught steelhead to their parents – also caught either by anglers or by trap – to test whether vulnerability to angling is a heritable “trait” in hatchery steelhead.

(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) and is an extension work developed by OSU M. Sc. student 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. 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 with the aid of 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.

Impact of Research:

Reports and Publications

Results of our research are given in numerous oral presentations and publications, selected examples are listed below. Presentations to the former OHRC Advisory Committee and the current Board at regular meetings are available on the OHRC website. Lists of earlier publications are presented in all our Annual Reports:

Clemens, B. et al. 2017. Conservation challenges and research needs for Pacific lamprey in the Columbia River Basin. Fisheries (in press).

Cogliati, K. et al. 2017. Early rearing experience and task learning behavior in juvenile steelhead, Oncorhynchus mykiss. Animal Behaviour (in review).

Cogliati, K. M., Unrein, J. R., Stewart, H. A., Schreck, C. B., Noakes, D. L. G. 2017. Variation in egg size and emergence timing: effects of early life history on morphology and behaviour in juvenile Chinook salmon, *Oncorhynchus tshawytscha*. Submitted to *Ecology and Evolution* (in review).

Cogliati, K. et al. 2017. Early life history, body morphology and behaviour in juvenile Chinook salmon, *Oncorhynchus tshawytscha*. Canadian Journal of Zoology (in review).

Cole, K. S. et al. 2017. Effects of stock source, family line and rearing temperature on gonad development in steelhead, *Oncorhynchus mykiss.* Copeia (in review).

Dittman, A. H., T. N. Pearsons, D. May, R. B. Couture & D. L. G. Noakes. 2015. Imprinting of hatchery-reared salmon to targeted spawning locations: A new embryonic imprinting paradigm for hatchery programs Fisheries 40: 114 – 123.

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. & K. M. M. Jones. 2016. Stress and behavior in fishes. In: C. B. Schreck & L. Tort (editors), Fish Physiology series, Academic Press.

Noakes, D. L. G. 2015. Book Review: A Foot in the Water. Quarterly Review of Biology (in press).

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.

Stewart, H. A., Noakes, D. L. G., Cogliati, K. M., Peterson, J. T., Iversen, M. H., Schreck. C. B. 2016 Salinity effects on plasma ion levels, cortisol, and osmolality in Chinook salmon following lethal sampling. Comparative Biochemistry and Physiology A. 192:38-43.

Thompson, N. F., C. A. Leblanc, J. D. Romer, C. B. Schreck, M. S. Blouin, D. L. G. Noakes. 2016. Sex-biased survivorship and differences in migration of wild steelhead (*Oncorhynchus mykiss*) smolts from two Oregon coastal rivers. Ecology of Freshwater Fish DOI: 10.1111/eff.12242.

Unrein, J. et al. 2017. Vertical self-sorting behavior in juvenile Chinook salmon, *Oncorhynchus tshawytscha*, implications for life history. Environmental Biology of Fishes (in review).

Unrein, J. et al. 2017. Evaluation of low-lipid starter diets to produce surrogate wild Chinook Salmon (*Oncorhynchus tshawytscha*): effects on growth, lipid content and feed conversions. North American Journal of Fisheries Management (in review).

Oral Presentations and Papers Presented at Research Conferences

Cogliati KM, Noakes DLG, Schreck CB. (September 2016). You are where you live: effect of rearing on fin quality of juvenile Chinook salmon. Gilbert Ichthyological Society Annual Meeting, Blue River, OR (oral presentation).

Cogliati, Karen M., David L. G. Noakes, Carl B. Schreck, Cameron S. Sharpe. 2016. Developing and delivering wild fish surrogate Chinook salmon and steelhead trout. Willamette Science Review, Feb 7-8, 2016.

Cogliati KM, Noakes DLG, Schreck CB, Sharpe CS. (February 2016). Developing and delivering wild fish surrogate Chinook salmon and steelhead trout. Willamette Fisheries Science Review, Corvallis, OR (oral presentation).

Munakata, A., D. Noakes, C. Schreck. 2016. Minute and slight water temperature decrease triggers hormone mediated downstream migratory behavior in Pacific salmon. International Symposium on Fish Endocrinology in Gothenburg, Sweden.

Noakes, D. 2016. OHRC: a research center in a natural environment. ODFW Hatchery Managers & Fish Biologists. Eugene, Oregon. 28 January 2016

Noakes, David L. G., Karen M. Cogliati, Carl B. Schreck, Cameron S. Sharpe. 2016. Determinants of migratory life history phenotypes in juvenile spring Chinook salmon. Willamette Science Review, Feb 7-8, 2016.

Noakes, D., E. Billman, K. Cogliati, C. Schreck. 2016. The Imitation Project. Oregon AFS, Seaside, Oregon. March 2016.

Noakes, D. 2016. The Oregon Hatchery Research Center: overview and update. Oregon Fish & Wildlife Commission, OHRC. 21 April 2016

Noakes, D. 2016. The Oregon Hatchery Research Center: research in progress. Northwest Power & Conservation Council, Portland, Oregon. 12 January 2016

Noakes, D. 2016. The Oregon Hatchery Research Center: research advances. Corvallis Rotary Club. February 2016.

Noakes, D. 2016. A tale of two salmon. Stream Team Seminar, OSU Fisheries & Wildlife. 15 February 2016

Noakes, D. 2016. Geomagnetic imprinting and navigation.
地磁気による記銘と航行 . NITOBE class, Hokkaido University. OHRC, 17 March 2016.

Noakes, D. 2016 Monitoring Estuarine Survival of Steelhead (*Oncorhynchus mykiss*) Smolts in the Nehalem and Alsea Basins, Oregon Using Acoustic Telemetry, NITOBE Class, OHRC. March 2016

Noakes, D. 2016. Steelhead Management. Hokkaido University, NITOBE Class, OHRC. March 2016.

Noakes, D. 2016. Research Update and Report. OHRC Advisory Board, June 2016.

Noakes, D., A. Dittman, J. Lemanski, M. Johnson, J. O'Neil, R. Couture 2016. Olfactory imprinting in salmonids. Ecology, Ethology and Evolution of Fishes Research Conference, Florida State University, Tallahassee, Florida. June 2016.

Noakes, D. 2016. The Oregon Hatchery Research Center. Oregon Wildlife Foundation Dinner & Auction. Portland, Oregon. 11 June 2016.

Noakes, D. 2016. OHRC Research Plan Meeting, Corvallis, Oregon. December 2016.

Noakes, D. 2016. OHRC Research Plan Update, Corvallis, Oregon. August 2016.

Noakes, D. 2016. The Oregon Hatchery Research Center: research updates. Douglas Timber Operators, Coos Bay, Oregon. 18 October 2016.

Noakes, D. 2016. Research Update and Report. OHRC Advisory Board, September 2016.

Noakes, D. 2016. The Oregon Hatchery Research Center: research updates. Douglas Timber Operators, Roseburg, Oregon. 8 December 2016.

Noakes, D. 2016. The Oregon Hatchery Research Center: Olfactory imprinting research. Port Orford, Oregon. 8 December 2016.

Noakes, D. 2016. Research for the Future. West Coast Salmon Summit, Canyonville, Oregon. 28 September 2016.

Noakes, D. 2016. Research Update and Report. OHRC Advisory Board, December 2016.

Noakes, D. 2016. OHRC Research Plan Meeting, Corvallis, Oregon. December 2016.

Noakes, D. 2016. Oregon Hatchery Research Center. Agriculture & Natural Resources Committee, Oregon House of Representatives, Salem, Oregon. 13 December 2016.

Putman, N. F., M. M. Scanlan, A. M. Meinke, L. C. Naisbett-Jones, K. A. Young, K. J. Lohmann, T. P. Quinn, A. P. Klimley, and D. L. G. Noakes. 2016. Ocean migration: navigating a dynamic geomagnetic environment. Oregon Chapter, American Fisheries Society, March 2016.

Scanlan, M. M., N. F. Putman, A. M. Meinke, R. B. Couture, J. P. O'Neil, and D. L. G. Noakes. 2016. Comparison of magnetic orientation responses of native and introduced salmonid species in the North Pacific Ocean. Oregon Chapter, American Fisheries Society, March 2016.

Scanlan, M. M., N. Putman, A. Pollock, R. B. Couture, J. O'Neil and D. L.G. Noakes. 2016. Magnetic orientation responses of native and introduced salmonid species in the North Pacific Ocean. Hokkaido University, Nitobe Class, OHRC, March 2016.

Scanlan, M., N. Putman, A. Pollock, and D. L.G. Noakes. 2016. Comparison of magnetic orientation responses three salmonid species in the northern and southern hemisphere. EEEF meeting, Florida State University, June 2016.

Scanlan, M., N. Putman, A. Pollock, and D. L.G. Noakes. 2016. Geomagnetic Orientation, a tool for long distance salmon migrations? Gilbert Ichthyological Society, September 2016.

Self, K. E., K. M. Cogliati, D. L. G. Noakes, C. B. Schreck. 2016. Egg size and growth in wild broodstock steelhead (*Oncorhynchus mykiss*). Oregon Chapter of the American Fisheries Society, Seaside, Oregon.

Self, K. E., K. M. Cogliati, D. L.G. Noakes, C. B. Schreck. 2016. Egg size and growth in wild broodstock steelhead (*Oncorhynchus mykiss*). 2016 Pacific Coast Steelhead Management Meeting, Asilomar, California.

Self, K. E., K. M. Cogliati, D. L.G. Noakes, C. B. Schreck. 2016. Egg size and growth in wild broodstock steelhead (*Oncorhynchus mykiss*). Japan Salmon Science Society, Sapporo, Japan.

Self, K. E., K. M. Cogliati, D. L.G. Noakes, C. B. Schreck. 2016. Egg size and growth in wild broodstock steelhead (*Oncorhynchus mykiss*). Hokkaido National Fisheries Research Institute, Sapporo, Japan.

Self, K. E., D. L.G. Noakes, H. Ueda. 2016. Using Genetics to Compare Olfactory Imprinting Ability between Hatchery and Wild Salmon from the Pacific Northwest of the United States. NSF EAPSI Final Presentation, Tokyo, Japan.

Self, K. E., D. L.G. Noakes, H. Ueda. 2016. Using Genetics to Compare Olfactory Imprinting Ability between Hatchery and Wild Salmon from the Pacific Northwest of the United States. 2016 Gilbert Ichthyological Society, Blue River, Oregon.

Stewart, H., C. Schreck and D. Noakes. 2016. Finding Your Wild Side: Production of Wild-Like Salmonids. World Aquaculture Society, February 22-26, 2016

Sharpe, C. S., Cogliati, K. M., Chitwood, R., Noakes, D. L. G., Schreck, C. B. (December 2016). Rearing strategies affect body morphology and caudal fin quality in juvenile Chinook salmon. 67th Annual Northwest Fish Culture Concepts, Grand Mound, WA (oral presentation).

Our research attracts attention, collaborators and joint research proposals. The impact of our research can be estimated by conventional methods, perhaps the clearest examples are from our recent publications on sockeye, Chinook and steelhead. Our research on geomagnetic orientation and navigation in Chinook, sockeye and steelhead has attracted considerable attention to the OHRC, with numerous requests for information and proposals for funding applications and research collaborations. Similarly, the ongoing OHRC Research Plan Projects (Michael Banks, Mike Blouin, David Noakes) are regularly cited in articles in the news media, as well as scientific journals.

Sample searches on the Web further indicate the impacts of our research:

https://www.google.com/?gws_rd=ssl#q=salmon+magnetic+navigation

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

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

Research Workshops

We continue our series of Research Workshops at the OHRC on a range of topics to meet the OHRC Mission (Lampreys, eDNA, Behavioural Ecology). 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 2016 and 2017, and served on the organizing and steering committees for the International Charr Symposium (Tromso, Norway) and the international biennial conference on Ecology, Ethology and Evolution of Fishes (Florida State University).

OHRC Mission Goal 3: Education and Outreach

Joseph O'Neil continued his activities at the OHRC and during visits to a number of schools in Lincoln County during 2016 as the lead person responsible the Education and Outreach activities at the OHRC. He was a key person in the OCAMP Science Education Project, and he continues as an active member of the Oregon Coast STEM project. He is 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 senior undergraduate courses in Fish Ecology (classroom and Distance Education) and a postgraduate class in Fish Ecology & Conservation (classroom and Distance Education). He continues to give invited lectures and seminars at OSU on Scientific Publishing, 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.