# Oregon Hatchery Research Center

# 2023 Annual Report

***To:***

**Oregon Legislature**

**State Fish and Wildlife Director**

**State Fish and Wildlife Commission**

***By:***

**Oregon Hatchery Research Center Board**

**February 1, 2024**

## Executive Summary

This is the eleventh annual report by the Oregon Hatchery Research Center (OHRC) Board to the Oregon Legislature, Oregon Department of Fish and Wildlife (ODFW) Director, and the State Fish and Wildlife Commission. Included in this report are accounts of:

- Composition and activities of the OHRC Board in 2023 and the Board's focus for 2024;
- The laboratory space transition from the Fall Creek Facility to the John L. Fryer Aquatic Animal Health Lab (AAHL);
- Continued implementation of the OHRC Strategic Research Plan to fulfill the Center's Mission and Goals, addressing previously defined research focus areas and newly identified priorities and management recommendations, including:
    1. If patterns of mate selection observed in the wild-spawning salmon populations can be emulated in hatcheries to improve the fitness of hatchery fish;
    2. If and how addition of odorants to hatchery water can improve olfactory imprinting by juvenile salmonids and homing of adults;
    3. How Tribal and non-Tribal entities who engage with recreational and commercial fisheries perceive hatchery management;
    4. If the time of the year and life history stage that juvenile fish are released from hatcheries affects the quality and abundance of returning hatchery adults;
    5. If and how hatchery rearing practices impose selection on salmonids that compromises their fitness in the wild, and how fitness differences between hatchery- and natural-origin fish might be reduced or eliminated;
    6. The feasibility of reintroducing salmon populations upstream of dams as well as providing the genetic basis for the listing of coastal Chinook Salmon stocks;
    7. How field researchers can measure juvenile fish growth using non-lethal blood draw methods;
    8. How various rearing practices might affect the microbiomes and immune systems of hatchery-origin salmonids; and

9. Investigations into the cause of fin erosion and opercular deformities in hatchery steelhead;

- Outreach and education activities conducted by staff and researchers of the OHRC; and
- Funding allocations of the last calendar year to support operations, outreach, and research.

A copy of this report can be obtained at https://www.dfw.state.or.us/fish/OHRC/news.asp

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## Introduction and Purpose

This report fulfills the Oregon Hatchery Research Center (OHRC) Board's requirement to report to the Legislative Assembly, the State Fish and Wildlife (ODFW) 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 OHRC research projects (ORS 498.827(6)).

Herein, we detail the activities of the OHRC Board during the 2023 calendar year, with relevant references to past activities; describe the funding and implementation of the Research Plan for the OHRC, as was adopted by the OHRC Board in 2014; and relate scientific information and recommendations produced through research conducted at the OHRC in 2023. This report also outlines the focus for the Board in 2024.

## The OHRC Mission

The **Mission of the Oregon Hatchery Research Center** (OHRC) is "to be an internationally recognized leader in fisheries science, conducting research to define the mechanisms that may create differences between hatchery and wild salmonids, recommending strategies to manage those differences, and educating Oregonians about the benefits, risks, roles and performance of hatcheries in fisheries augmentation and conservation".[1]

The three defined **Goals of the OHRC** are 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.

[1] https://www.dfw.state.or.us/fish/ohrc/mission.asp

c. Determine the possible genetic and ecological consequences of hatchery fish and their releases on native fish at each life history stage.

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.

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.

## The OHRC Board in 2023

### Board Composition

In December 2023, two new members were appointed to the OHRC Board. Ms. Anna Le and Dr. Randall Brummett were appointed as representatives for Sport Angling.

Anna Le (she/her) is an Aquatic Biologist, Environment Educator, and Science Communicator. She is also the founder of Grayling Education, an environmental education consulting company dedicated to engaging people and inspiring the next generation of stewards by learning about conservation and science through intentional place-based learning, storytelling, and education. Anna obtained her B.S. in Fisheries and Wildlife Sciences from Oregon State University and is

currently a graduate student at Montana State University, earning an M.Sc. in Science Education. Her adventurous career has led her to travel extensively throughout the West, working with different watersheds and salmonid species, educating student groups in places like Yellowstone National Park, canoeing and photographing the Rio Grande River, flyfishing wild and scenic rivers, and continuing to bridge the gap between conservation and education as well as getting more people engaged with the natural world.

Randall Brummett is a retired fisheries and aquaculture specialist. After obtaining a PhD in fisheries at Auburn University, he spent 30 years in the Near East and Africa building fish farms, teaching aquaculture and fisheries biology, and undertaking a wide range of research and extension projects focusing on aquaculture, fish biodiversity and community-based fisheries management systems. He joined the World Bank as a Senior Specialist in 2010 where his job was to develop a portfolio of investments in sustainable aquaculture and fisheries. Randall worked with a wide range of academic and policy teams on projects around the world to explore ecosystem approaches to fisheries and aquaculture, environmental and disease management, the potential of recreational fisheries as a development intervention, and the interaction between hydrological infrastructure and fisheries.

The composition of the OHRC Board, as of December 31, 2023, is presented in Table 1.

Table 1: OHRC Board members by interest group and term expiration date.

| Position | Voting Status | Member | Term Expiration |
|---|---|---|---|
| Oregon Salmon Commission | Voting | Dwight Collins | 06/30/25 |
| Columbia River Gillnet | Voting | Derek Wall | 06/30/25 |
| Wild Fish Advocacy | Voting | Tom Alkire | 06/30/25 |
| Wild Fish Advocacy | Voting | Seth Isenberg | 06/30/23 |

| | | | |
|---|---|---|---|
| Sport Anglers | Voting | Anna Le | 06/30/27 |
| Sport Anglers | Voting | Randall Brummett | 06/30/27 |
| Agriculture | Voting | Ted Simon | 06/30/24 |
| Coastal Ports | Voting | Chuck Pavlik | 06/30/24 |
| Forestry | Voting | Scott Starkey | 06/30/27 |
| Independent Science | Voting | Steve Jacobs | 06/30/25 |
| Fish Habitat Restoration | Voting | Peter Gruendike | 06/30/25 |
| Oregon Indian Tribes | Voting | Travis Mackie | 06/30/25 |
| Federal Agency | Non-voting | Lance Kruzic | Indefinite |
| OSU | Non-voting | Carl Schreck | Indefinite |
| ODFW | Non-voting | Shaun Clements | Indefinite |

## Board Meeting Summaries

Agendas and minutes for all OHRC Board meetings are posted on the center's website at https://www.dfw.state.or.us/fish/OHRC/minutes.asp. A brief overview of each meeting is below:

The first OHRC Board Meeting of 2023 was held on January 20th. In this meeting, the Board reviewed new proposals for research with the goal of selecting two additional projects. A poll from all members clearly identified the two highest ranked projects: Dr. Marc Johnson's Rearing and Release Strategy Impacts on Quality and Abundance of Returning Adult Hatchery Salmon

and Dr. Kelly Biedenweg's Public Perceptions of Oregon Hatcheries for Outreach and Engagement. This was accompanied by a motion to decrease the budgets of all four studies by 8% to allocate funding for the new projects.

The second Board Meeting was held on March 15th and included overviews of presentations given at the Oregon Chapter of the American Fisheries Society meeting in Eugene, status updates from previous and currently funded research projects, and a conversation about the ongoing water quality issues at the Fall Creek facility amid progression of the landslide upstream. Dr. Shaun Clements provided information about several proposed bills in the legislature that would affect ODFW's ability to monitor streams. Lance Kruzic presented an overview of Coho Salmon recovery on the Oregon Coast as a part of the NOAA 5-year status review of ESA-listed salmon and steelhead in the region. This was followed by a discussion of 2023 board activities such as suggested speakers and workshops.

The next meeting was held on June 27th. Director White introduced new OSU personnel and Jen provided staffing updates at the Fall Creek facility. A primary discussion topic of this meeting was how to use OHRC funded research to provide management recommendations to the legislature regarding hatchery management. A plan was developed to integrate sections regarding management recommendations for each study into the annual report. The OHRC Board heard updates and recommendations from the funded projects and discussed delaying the timeline of recommendations until data from the fall 2022/winter 2023 fish return was collected and analyzed. Jen provided updates on OHRC outreach activities and Director White elaborated on highlights from a technical meeting regarding the Fall Creek landslide. General takeaways from the meeting are that there is a low but non-zero risk of catastrophic hillslope failure that will very likely cause persistent and lasting water turbidity issues during intense rain concurrent with cold weather (November-March). There are already extremely well-functioning hazard communication and response protocols in place and some mitigation measures discussed were promising but would require funding. A discussion about a workshop focused on the use of hatch boxes followed before the meeting was adjourned.

The September 12th meeting started with updates from Jen Krajcik that ODFW staff would be transferred to other positions following the temporary hiatus of the Fall Creek facility due to water quality complications from the landslide upstream. The Board then heard from PIs about project-specific updates, followed by a discussion of hatch boxes, and then a motion to redistribute funds from a previous broodstock study to a current study on fish gut microbiomes. Guest presentations were given by Dr. William Jaeger (OSU) about restoration spending in the Columbia River basin and Dr. Hannah Harrison (Dalhousie University) about hatchery practices in the face of climate change. Dr. Brian Erickson led a discussion regarding the new Public Perceptions of Hatcheries project.

At the last meeting of the year on December 12th, the Board toured the Aquatic Animal Health Lab (AAHL) in Corvallis where Fall Creek facility research operations will temporarily resume. The Board continued the meeting on the OSU campus where Tom Stahl (ODFW) introduced new members Anna Le and Randy Brummett, representing Sport Anglers. Tom Stahl brought the OHRC Board statutes (ORS 498.827) and Charter and the Oregon Government Ethics Commission's *Guide for Public Officials* to the Board's attention for review regarding roles and responsibilities of members. OSU research assistant Ashley Sanders provided information about the transition of research operations from the Fall Creek facility to AAHL as well as new protocols for monitoring turbidity at Fall Creek. Plans for the creation of a documentary by local filmmakers Freshwaters Illustrated were discussed as a primary OHRC outreach project in 2024. The Board proceeded into a discussion regarding the direction of future research before the next legislative session in 2026. Dr. Jessica Miller gave an update on the Timing of Release Project, then Peter Gruendike and Mark Hereford presented some information about the dam removal process and biological monitoring in the Klamath Basin.

### Board Focus for 2024

- Review and evaluate the 2014 OHRC research plan;
- Develop and/or refine management recommendations based on OHRC research as appropriate;
- Conduct a workshop on the state of knowledge regarding egg incubation box ("hatch box") benefits, risks, and effectiveness;
- Recruit Wild Fish Advocate to the OHRC Board

## The OHRC Activities in 2023

### Overview

With reference to the **Mission** and **Goals** of the OHRC, the following activities and projects were developed, continued or communicated at or through the OHRC in 2023:

Goal 1 - *Understand mechanisms that may create differences between hatchery and wild fish*:

1.a. Domestication selection project (steelhead) – Blouin et al.

1.a. Identifying hatchery rearing conditions that reduce stress and improve immunity – Couch et al.

1.b. Surrogate wild salmonids project– Schreck et al.

1.c. Genetic propensity to be caught by anglers ("Biter Study") – Johnson et al.

Goal 2 - *Develop approaches to manage hatchery fish that conserve and protect native fish*:

2a. Effects of thiamine supplementation on survival and performance of hatchery fish – Reed et al.

2.a., b. Identifying hatchery rearing conditions that reduce stress and improve immunity – Couch et al.

2.b. Mate choice –Banks, Auld, Jacobson

2.b., c. Effect of hatchery rearing conditions on steelhead behavior – Blouin

2.d. Olfactory imprinting and homing of Chinook Salmon –Dittman, Johnson, Quinn, White, May, et al.

Goal 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*:

3.a. The OHRC re-opened to the public in May of 2022, and hosted student groups for classes on fish culture, pathology, anatomy, conservation, and ecology.

3.b.d. OHRC staff taught classes, hosted the ODFW Aquatic Inventories Annual Training, and held a Free Fishing Day Event.

3.c. OHRC reared fish for several OSU classes, including Introduction to Aquaculture.

3.e. OHRC staff engaged with the fishing public in outdoor areas of the OHRC.

3.f. Research conducted through the OHRC was published and presented at scientific workshops and symposia during 2023.

3.h. Results from OHRC research were disseminated through scientific publications, theses, and reports

## Facility Transition

The Fall Creek facility near Alsea, OR is the original site of OHRC research operations, but has been temporarily closed due to the progression of a landslide upstream in the Fall Creek watershed. In recent years, the facility has experienced operational challenges as the landslide continues to introduce suspended sediments to water used for fish rearing. High suspended sediment loads increase pathogen exposure for fish, compromising juvenile fish survival for experiments that require careful planning for sample size, rearing conditions, etc. Even though an alarm system exists to warn personnel of large landslide movements, the landslide also poses a danger to the staff working at the facility since the exact behavior of the material during the event cannot be completely predicted. After much consultation and deliberation between OSU and ODFW, it was determined that operations at the facility would be halted temporarily with the qualification that the facility would be maintained for operations to resume with a lead time of one month. The facility was secured for temporary closure and protocols were established to keep the facility available to resume activities if needed. One ODFW staff member remains on-

site to conduct routine maintenance and care, while remaining staff have transferred to other agencies.

Water quality in Fall Creek is currently monitored to determine if it will be feasible to resume fish rearing operations at the end of the temporary closure. Research assistant Ashley Sanders has initiated a qualitative assessment of water quality by deploying two trail cameras aimed at different river sections near the facility, set to take photos every 10 minutes in the daytime. Nathan collects grab samples every week and at each high turbidity event, which are processed on a benchtop turbidity reader. The point measurements may allow for a quantitative calibration of the photos and will offer a time series of maximum turbidity levels over time. Though there is not a known threshold at which turbidity negatively impacts fish rearing, the photos will lend insight into how many days per year the water is generally turbid and if the frequency of turbid days is increasing over time.

Experiments associated with or supported by the OHRC are planned to be conducted at the Aquatic Animal Health Lab (AAHL), an OSU fish research facility in Corvallis. The AAHL operates a highly controlled system that allows researchers to modify water source and temperature with a high degree of precision. The OHRC, in conjunction with Dr. Seth White's Fish Behaviorscapes Lab at OSU, was allocated a dry lab room, limited interior and exterior storage space, an office space, and will be renting shared space in the wet lab. Pertinent lab equipment (scales, microscopes, etc.) as well as some larger fish rearing equipment (Heath trays) have been labeled, transferred to AAHL, and documented on an inventory list provided to ODFW.

Preparation for rearing fish for the Olfactory Imprinting Project began in November 2023, and the first batch of Elk River Chinook Salmon eggs were delivered to AAHL in January 2024. Other collaborative laboratory experiments are planned for the next year (trace pathogen detection with Dr. Claire Couch and epigenetic markers with Dr. Hayley Neutzel). An Animal Care and Use Permit (ACUP) from the Institutional Animal Care and Use Committee (IACUC) was obtained for fish culture and handling at AAHL. The laboratory space is also compliant with OSU's Environmental Health and Safety (EH&S) standards, including updated chemical inventories, personnel training, and safety equipment.

## Research Updates and Management Recommendations

Throughout the course of 2023 the OHRC continued to implement its Strategic Research Plan[2], which was developed and approved by the Board in 2014, with research funding sources secured in 2015. The OHRC Strategic Research Plan describes the OHRC's goals and several research focus areas aimed to meet those goals.

To address research focus areas identified in the 2014 plan, three research projects were proposed, approved by the Board, and initiated in 2016. These three projects were designed to test 1) mechanisms of domestication selection in hatcheries, 2) effects of mate choice on fitness of hatchery salmon, and 3) the methods to improve homing by hatchery salmon. The project aimed at exploring mechanisms of domestication led by Dr. Michael Blouin ended in 2023 after that research concluded making simple changes to hatchery rearing cannot overcome domestication selection. The funding for this research (accompanied by a partial reallocation of funding from the other existing projects) was reallocated to two new projects approved by the Board in 2023. One is aimed at understanding Tribal and non-Tribal fisherperson attitudes towards hatcheries and the second is an analysis of the differences in adult return rates of juvenile fish released from hatcheries at different times to represent different early life history strategies. The two original projects, which are described in the OHRC's Strategic Research Plan and initiated in 2016, continued through the course of 2023, per recommendations of the OHRC Board. Here, annual progress made by each of these projects, as well as previously funded or OHRC associated projects, is briefly described, with more detailed information in Appendix 1.

Research conducted by and through the OHRC in 2023 served to build upon the Center's record of producing actionable science in the field of fisheries management. Ongoing projects progressed toward delivering new tools to manage genetic and ecological risks from hatchery salmon and steelhead, and new projects identified practices to improve the health and survival of Oregon's salmon and steelhead.

### OHRC Funded Projects

#### Domestication Selection

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 through 2023.

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

This work is motivated by the observation that hatcheries appear to select for improved performance in the hatchery, but at the cost of reproductive fitness in the wild (production of offspring that survive to adulthood). The researchers hypothesize that larger size of juvenile steelhead and salmon at time of release from hatcheries is favored (selected for) because it predicts greater survival at sea. Therefore, behavioral or physiological traits that promote fast growth in the novel hatchery environment are likely to be propagated by current hatchery practices, but those traits come at a cost to offspring survival in the wild. Dr. Blouin's lab has investigated how hatcheries might be changed to produce fish that are genetically more like wild fish. This involves 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, and thus domestication.

Management recommendations: Research being conducted by Dr. Michael Blouin's lab was aimed at testing whether alterations to standard hatchery practice can produce fish that are genetically more similar to wild fish. Being able to raise hatchery fish that have genetic fitness more like that of wild fish might allow managers to increase pHOS or other measures of hatchery influence, creating more opportunities for angling and harvest. Current findings from this project indicate there are no simple ways to significantly reduce the opportunity for domestication selection in hatcheries (e.g., by adding structure, increasing flow, or reducing density) at a production scale beyond grading size classes to create more even size distributions among families.

### Wild-like Mate Choice

The project headed by Drs. Michael Banks and Heather Auld (testing wild-like mate choice to improve hatchery fish) advanced as planned in 2023. Continuing with Phase 3, 2023 was the second year wherein all Coho Salmon returning to Sandy Hatchery were offspring from experimental spawns. Through a total of five visits to the hatchery, Dr. Banks and research assistant Dave Jacobson worked with ODFW staff to sample all returns (4,054), that included 3,041 adults (2020 spawn offspring) and 1,013 jacks (2021 spawn offspring). Given the workload associated with manually sampling thousands of Coho per day, they have continued to work with the Hatfield Marine Science Center's Innovation Laboratory to develop a technology to automate sampling. Efficiency gained through this novel device dubbed the "VALUE TAGGER" has potential to transform salmon tagging through providing access to a broad array of new information in near-real-time. Efficiency of digital archive and access will better inform and enable harvest, management & conservation strategies and needs of the future. Primary effort in 2023 has been to develop relationships with Engineers and Industrial Partners including expertise in computer vision and deep learning to add estimation and archive of species, sex, length, weight and condition of hatchery salmon using artificial intelligence (AI) at a rate of

1,000s per day. This partnership also includes an advisory panel of 9 scientists, biologists and professionals from private business, hatcheries, and management agencies distributed across the PNW. The entire team has now developed and completed a compelling proposal currently in review with the National Science Foundation Partnership for Innovation Program. Fingers crossed that a positive selection decision will add an investment of ~$1,000,000 to this initiative.

Dr. Banks and Dave Jacobson also participated in the Coho Salmon spawn at Sandy Hatchery in 2023, taking and archiving DNA samples from all broodstock. They also continued pedigree analysis of ongoing returns from experimental spawns. This includes jacks and adults from the 2019 and 2020 spawns, and jacks from 2021. Given promising results for all signature sampling points analyzed to date, Dr. Banks has begun to share findings with the community through presentation at 5 different professional science/public venues in 2023.

Management recommendations: The researchers have coordinated with hatchery managers to achieve a production-scale generation of Coho Salmon to test their hypothesis of improved fitness through wild-like mate pairings, guided by molecular genetic information for three consecutive years (2019, 20 & 21). If results continue to remain positive and convincing, then "wild-like" breeding strategies at production hatcheries could greatly increase hatchery contributions to marine and inland fisheries. Offspring from 'wild-like' bred hatchery fish might also have closer reproductive success to wild fish, and thus reduce their potential impacts upon wild fish. In accord, updated results will also contribute to a panel discussion titled: *Aquaculture-aided fisheries enhancement, conservation, and restoration: Towards responsible development and effective reform* at the World Fisheries Congress to be held in Seattle March, 2024. They will also be shared with the Columbia River Coho group and Umatilla Tribal Hatchery at their next meeting (February 2024) as part of an exploration into methods that could be applied to increase the performance of their Coho hatchery stocks.

### Olfactory Imprinting

The Olfactory Imprinting Project led by Drs. Andy Dittman, Thomas Quinn, Seth White, and Marc Johnson made progress addressing three key hypotheses of the project: 1) in-river straying increases when salmon can't effectively distinguish the olfactory cues of the hatchery from the river water that supplies the hatchery, 2) rearing of salmon embryos in river water may be beneficial for improving olfactory development and homing fidelity, and 3) the timing of odor exposure and release may be critical for successful olfactory imprinting.

The management-scale field experiment at Elk River Hatchery (ERH) addressing the first hypothesis continued in 2023. The experiment was designed to test whether Chinook salmon

exposed to a unique bouquet of amino acids as juveniles display higher homing fidelity to their natal hatchery than control fish not exposed as juveniles, when the same chemicals are added to water leading into the hatchery. This experiment was initiated in 2020, replicated in 2021 and 2022, and treated fish will continue returning through 2026. In early 2023, the third year of the amino acid odors were delivered at the ERH adult return ladder and experimental salmon returning to the Elk River were collected. During the 2023-2024 return year, 1245 experimental salmon were recovered at the hatchery, 192 were recovered in the sport fishery, and 50 were recovered on the spawning grounds. Lab experiments were initiated to test the efficacy of additional complex, less expensive imprinting odor solutions and to develop physiological and molecular markers of imprinting that will facilitate future assessments of imprinting success. Analyses of these data will be completed by the end of 2024.

To test whether embryonic rearing water influences successful imprinting, a two-brood year study at the ERH was initiated in 2017, wherein embryos were incubated in either Elk River water or well water (per conventional hatchery practice). In June of their first year, juveniles were given treatment- and raceway-specific coded wire tags and released in the fall. Adults from these studies were recovered at the hatchery ladder and spawning grounds in 2019-2022 with the final experimental fish returning Fall 2023. The final returning experimental fish have been recovered at the ERH and Elk River spawning grounds. Coded wire tags will be decoded in 2024 and improvements in homing fidelity will be assessed by comparing differences in hatchery returns between the well water and river water exposure groups. Two manuscripts describing the results and management implications of this study will be completed in 2024-2025.

To explore how timing of odor exposure and release affects imprinting in ERH salmon, laboratory studies were designed to measure several physiological and endocrine metrics associated with smolting and imprint timing. Analyses of these samples were completed in 2021 and suggest that two important periods for odor exposure are late Spring and just prior to release. These findings have been incorporated into odor exposure experiments and final reports and publications on this work will be submitted in 2024.

A new component of this research in the 2023-25 biennium includes analysis of homing and straying of hatchery fish at a regional scale in the face of climate change. Progress on this front includes bringing on a new PhD student (Miriam “Mimi” Obley) to OSU in January of 2024, supervised by Dr. Seth White. Mimi will be drawing information from a concurrent ODFW climate change vulnerability assessment and analyzing a large coded-wire tag (CWT) dataset from Oregon coastal hatcheries.

Management recommendations: Results from the Olfactory Imprinting Project will be used to better understand the physiological mechanisms that drive accurate homing in Pacific salmon, as

well as provide insights into how hatchery practices influence those mechanisms. Historically, hatcheries have not prioritized water source as an important consideration in maintaining segregated fisheries systems, but research on olfactory imprinting from this research enterprise has shown that even subtle changes in water chemistry in early life history stages can have profound implications for an individual's ability to return to a natal stream or a hatchery as an adult. Results from the large-scale field experiments, as well as the investigation into economically feasible and readily available odorants, may be used to develop realistic hatchery protocols to promote more accurate homing in segregated systems where in-river hatchery straying is not desirable. Findings from the larger-scale straying analysis are expected to inform hatchery practices that reduce straying of hatchery fish in the face of climate change.

### Perceptions of Hatcheries

The focus of Dr. Kelly Biedenweg et al.'s research is on understanding public perceptions of salmonid hatcheries from fishers and identifying subgroups with similar beliefs about hatcheries. The study is premised on the idea that understanding where people are coming from – their existing beliefs and experiences – is critical for effective communication. To study perceptions of hatcheries, this project focuses on two primary audiences: Tribal communities and non-Tribal fishing communities. Semi-structured interviews and Traditional Ecological Knowledge methods are used as primary research methods.

In their first six months, study design is complete and IRB (ethics board) approval has been obtained for both Tribal and non-Tribal portions of the study. Researchers are continuing engagement with all nine federally recognized Tribes of Oregon. This involves review by respective Tribal committees, applying for research permit licenses via each Tribe's internal IRB equivalent, and drafting MOUs if and when a Tribe requests the document. No document requests have been made as of yet. Formal approval has been obtained from 4 Tribes (Klamath, Cow Creek, CTCLUSI, Siletz), with verbal agreement from Warm Springs and unofficial agreement from two Grand Ronde Department of Natural Resource members. As anticipated, the process is taking time since Tribes are sovereign and have internal government structures with timelines that do not always coincide with mainstream government or agency timelines. Researchers are working within these timelines to fulfill each research request per Tribal constitutions and legal ordinances. Interviews with Klamath (via Zoom) and Siletz Tribes (in person) were scheduled for February 2024. Cow Creek and CTLUSI will be in February as well, and scheduled into March and April 2024. Klamath has referred seven Tribal members for interviews, and the Siletz Tribe has six members who have expressed interest. Neither Tribe has had public recruitment material sent out yet, so there will likely be more interest in sharing perspectives via interview processes once the Tribal memberships at large are notified.

CTCLUSI has four members who have indicated interest, and three from Cow Creek so far, all without advertisement as well.

On the non-tribal side, 15 semi-structured interviews have been completed with individuals of varied affiliation (e.g., fishing guides, conservation organizations, sport fishing advocates, seafood businesses, hatchery workers). An initial round of analysis is underway to identify emerging themes and potential gaps requiring additional sampling. To further increase the amount and range of comments available for analysis, researchers are exploring ways to use topic modeling to identify themes in existing salmonid hatchery-focused public comments and discussion forum posts.

Management recommendations: While the findings from this study are intended to inform the development of outreach and education efforts around hatcheries science and management, there are no findings yet to report.

### Timing of Release

Along the Oregon coast, seven ODFW hatcheries propagate fall-run Chinook salmon for release into the Lower Columbia, Nestucca, Trask, Salmon, Lower Umpqua, Elk, Coos, Coquille, and Chetco rivers. These hatchery programs are operated almost entirely for the purpose of harvest augmentation, except for a recently established conservation hatchery program for Coquille River fall Chinook. Given increasing river temperatures, variable flow regimes, and changing ocean conditions, existing release strategies may not be sufficient or cost-effective as conditions change. The goal of this study is to examine rearing and release strategies for juvenile hatchery Chinook salmon and identify those that optimize the quality and abundance of returning adult salmon, carried out under current climatic conditions and with existing hatchery infrastructure. To achieve this goal, researchers will collaborate with ODFW to evaluate the performance of existing and novel release groups of fall Chinook salmon within the Klaskinine, Trask, Coos, and Elk Rivers.

This project originally included Marc Johnson, who recently left ODFW for a new position with NOAA Fisheries in Portland. Since that time, ODFW assigned Brent Hinners to serve as a liaison between ODFW and the remaining PIs from OSU (J. Miller) and NOAA (B. Beckman). Some additional funds were added to the OSU budget for project management and coordination, which originally were proposed to be completed by M. Johnson. These changes delayed progress somewhat. However, several productive project meetings have occurred with ODFW personnel on April 20, June 14, July 7, and Oct 10, 2023, and Jan 5, 2024. These meetings led to a finalization of a release and tagging plan for the 2023 brood year (2024 release year), which

includes the addition of three new CWT releases (30,000 in each group) in the Klaskinine, Trask, and Coos hatchery systems. The returns associated with these releases will be compared with each other and with releases from the Elk River Hatchery, which already have a full complement of CWT. Confirmation was acquired from Lance Kruzic from NOAA that "the proposed adjustments to hatchery releases, earlier release of hatchery salmon, would not be an issue with respect to the ESA authorization of the Trask hatchery program/HGMP and effects on coho salmon. Releases of hatchery fish would not increase. NMFS does not expect any additional effects on listed coho salmon from the proposal and the actions would continue to be covered by the existing ESA authorization for this hatchery program." See Appendix 1 for a detailed fish release schedule from each hatchery program associated with this project.

Management recommendations: This research is expected to generate actionable recommendations for juvenile salmon rearing and release strategies by quantitatively comparing existing and new release groups. Ideally, over the next year, researchers will also determine what, if any, manipulations to rearing conditions (temperature, feed, etc.) would be possible in the second year of releases (2025). Given the duration of marine residence and the variable age-at-maturity for coastal Chinook salmon populations, full analysis of survival data will take several years. Overall, the knowledge generated can inform hatchery practices and, potentially, also identify infrastructure needs that facilitate the development of more resilient hatchery rearing strategies in light of projected future environmental variation.

### Fish Microbiomes

Dr. Claire Couch received $50,000 from the OHRC in 2022 to support her ongoing research on optimizing rearing conditions of Pacific salmon for hatchery production and conservation. Dr. Couch's central research question is: Can alternative rearing strategies enhance disease resistance in hatchery-origin salmonids, thus increasing post-release survival and reducing the effects of hatcheries on natural-origin salmonids? By enhancing disease resistance, hatcheries would need to release fewer fish to achieve the same smolt-adult returns, thus reducing effects on hatchery releases on wild juveniles. Additionally, enhancing disease resistance in hatchery fish would reduce the risk of disease transmission to wild fish. Specifically, Dr. Couch's work focuses on how diet, rearing conditions, and stress relate to immune function, the microbiome (i.e. communities of bacteria and other microbes that live on and in fish), disease susceptibility, and ultimately, the health and survival of Pacific salmon.

In 2023, Dr. Couch completed and/or advanced several projects that are relevant to the OHRC mission. First, she completed and published a study on the effects of chronically elevated corticosteroids (i.e. stress hormones) on microbiome composition and mortality risk, which has

important implications for managing and monitoring juvenile fish in hatcheries as well as adult fish returning to spawn (Couch et al. 2023). In a separate but related study, Dr. Couch worked with collaborators at University of New Mexico to complete a study on how the brain microbiome of salmonids changes throughout maturation and development (Mani et al. 2023). Dr. Couch is also collaborating with the Kent lab at OSU to complete a follow-up study on the combined effects of stress hormones and senescence-associated microbes on gut degradation and mortality, with the ultimate goal of understanding the causes of pre-spawning mortality in wild and hatchery populations of Chinook Salmon. Findings may ultimately be relevant to future studies on behavior, immunity, and pre-spawning mortality in wild and hatchery fish. Finally, Dr. Couch and her team continued to analyze samples from her OHRC-funded project. The purpose of the OHRC-funded experiment was to test the effects of diet on the microbiome, immune function, and disease resistance in juvenile Chinook Salmon. We have completed microbiome and transcriptome sequencing, as well as a preliminary analysis of these results. These preliminary results indicate that diet significantly alters the gut microbiome over a relatively short time scale, as well as the expression of genes are related to stress and smolting. Diet also indirectly influences growth, which appears to affect the activity of innate immune proteins in the blood. Dr. Couch is currently working with an undergraduate research student to conduct an experiment directly testing the effects of diet on disease susceptibility.

Management recommendations: Potential management applications of research led by Dr. Claire Couch include development of novel biomarkers to monitor the health of fish in hatchery settings and in rivers, and the development of rearing practices that support healthy microbiomes, immunity, and post-release survival in juvenile salmonids. Specifically, one of Dr. Couch's recent publications (Couch et al. 2023) demonstrates that the microbiome predicts mortality in chronically stressed Chinook Salmon. These findings suggest that a nonlethal, microbiome-based biomarker could be used to monitor population health, especially during times when stress hormones are elevated (e.g. smolting, migration, sexual maturation). Additionally, Dr. Couch's current OHRC-funded research on diet, microbiome composition, and immunity has the potential to reveal new avenues for mitigating disease susceptibility in hatchery-reared juveniles while minimizing the use of antibiotics. Overall, Dr. Couch's ongoing work will contribute to low-cost monitoring and sustainable management of both hatchery-origin and natural-origin salmon in the Pacific Northwest.

## Fish Genetics

Dr. Kathleen O'Malley directs the State Fisheries Genomics Lab (SFGL) which conducts research to address the science and management needs of Oregon State University's Coastal Oregon Marine Experiment Station and the Oregon Department of Fish and Wildlife. The SFGL provides leadership in the production of genetic data and the development of science-based tools and recommendations from those data for freshwater, anadromous and marine fishes.

In 2023, the SFGL's salmonid research focused on Chinook salmon, steelhead, chum salmon, and coho salmon. Here, we highlight three major research areas. The first is the evaluation of reintroduction programs for threatened spring Chinook salmon in the North Santiam and South Fork McKenzie rivers. Results indicate that spring Chinook salmon released above dams in these two systems are not replacing themselves. These findings were published in two U.S. Army Corps of Engineers Technical Reports and presented to a broad audience (USACE, NMFS, ODFW, academics, consulting agencies, etc.) at the annual Willamette Fisheries Science Review in Corvallis. Based on recommendations outlined in the reports, state and federal agencies decided to modify the reintroduction programs in these systems. The SFGL is currently evaluating spring Chinook salmon reintroduction programs in the South Santiam River and Fall Creek.

A second major research effort was initiated in response to recent petitions to list Chinook salmon. To help fill critical information gaps, the SFGL collaborated with ODFW to collect tissue samples from Oregon coast Chinook salmon. The samples were processed, and the genetic data was analyzed by the SFGL. Results were communicated to NOAA Fisheries to help inform their decision regarding the petitions. Based on the findings and subsequent discussions, 500 additional samples were collected in the Umpqua Basin. These samples will be processed, analyzed, and combined with prior data. Dr. Kathleen O'Malley is working to obtain funding to support this effort.

A third major research effort is centered on the Klamath Basin where a fourth dam was recently breached reconnecting over 400 river miles and restoring fish passage to historic habitat. Prior to dam removal, the SFGL conducted a genetic monitoring study of *Oncorhynchus mykiss* in this basin and is currently summarizing the results in a publication. Moving forward, the SFGL is coordinating with multiple state, federal and tribal agencies to monitor the re-establishment of anadromous fishes in this basin.

The SFGL established and maintains a tissue sample repository and database. The repository consists of over 140,000 archived tissue samples. Approximately 90% of the samples were collected from Chinook salmon and steelhead, and ~ 7,000 of these were collected at the Oregon Hatchery Research Center.

### Growth Hormone Indicator Study

A research team from the Columbia River Inter-Tribal Fish Commission (CRITFC) conducted a study with the goal of developing the use of the plasma hormone insulin-like growth factor-1 (IGF1) as an indicator of recent growth status in field studies on juvenile salmonids. The research team consisted of CRITFC scientists Anna Ringelman, Dr. Matt Kaylor, and Casey Justice, physiologist Dr. Andrew Pierce, and biologist Neil Graham. Before employing blood sampling in field studies on ESA-listed juvenile salmonids, it is necessary to determine the minimum size of fish that can be sampled to provide enough plasma to run the IGF1 assay without causing mortality or sublethal negative effects on the fish. To this end, a study was conducted at OHRC Fall Creek facility using juvenile rainbow trout. The effects of drawing a 100 µl blood sample on mortality, growth, and hematocrit were compared across a range of sizes expected to be encountered in field studies (90-170 mm) over the following 4 weeks. Unfortunately, an unacceptable level of mortality (20-40%) was observed across all size classes. Puzzlingly, however, mortality did not begin until about 10 days post-sampling and did not decrease as expected with fish size. In fact, the largest size class (160-170 mm) experienced the highest mortality rate. These levels of mortality have not typically been seen after drawing a similar volume of blood from juvenile salmonids over 120 mm. This led the research team to speculate that an interaction between water quality at the Fall Creek facility and the needle puncture wound from blood sampling may have led to secondary infections that influenced the mortality results. Blood sampling had little effect on hematocrit or post-sampling growth, suggesting that the fish were able to replace lost red blood cells over the 4-week period. Ongoing work will use the plasma samples collected to validate modifications of the IGF1 assay and binding protein extraction procedure to use smaller plasma volumes.

### Surrogate Wild Salmonids

In 2023 the U.S. Army Corps of Engineer-supported Surrogate Project reared deliverables at the OHRC Fall Creek facility. In January of 2023, Surrogate Project personnel transported 5,000 BY21 South Santiam spring Chinook to the OSU Fish Performance and Genetics Lab (FPGL) in anticipation of spring 2023 tagging events by Pacific Northwest National Laboratory personnel. One group of these individuals was released into Foster Reservoir for juvenile downstream dam passage studies. Unfortunately, the remaining fish from this group suffered from multiple

illnesses including bacterial kidney disease (BKD), furunculosis, and cold-water disease. Under advisement from ODFW pathologist Aimee Reed and in consultation with our collaborators with the USACE and PNNL, the fish were not deemed suitable for further release studies and were subsequently euthanized.

In late January we transported 2,000 BY22 North Santiam winter steelhead to the FPGL for a spring 2023 tagging event by PNNL personnel for release into Foster Reservoir. During the fall of 2023, Surrogate Project personnel conducted three additional transports of BY22 deliverables from the OHRC Fall Creek Facility to the FPGL. This included 4,200 North Santiam winter steelhead (2,000 Foster fall 2023 release, 2,200 Foster spring 2024 release). Additionally, 7,000 BY22 South Santiam spring Chinook salmon were transported to the FPGL in late October 2023 for spring 2024 tagging events for release into Foster and Green Peter Reservoirs.

Two experiments were conducted at OHRC's Fall Creek facility, the Stress Test and the Fin Damage Genesis Study. For the Stress Test, steelhead trout (*O. mykiss*) from Alsea Hatchery were reared from the eyed egg stage. After fish had absorbed their egg sacs, fish were transferred to 6 ft tanks at high and low density with and without structure as described in Herron et al. (2023). Originally the experiment was to be run in triplicate, but due to water quality issues, it was reduced to duplicate replicates. After experiencing a transport simulation stressor (Herron et al., 2023) plasma was collected for cortisol analysis. Samples have yet to be analyzed, results are expected to be collected by mid-2024.

For the Fin Damage Genesis Study, steelhead trout (*O. mykiss*) from Alsea Hatchery were reared from the eyed egg stage. Embryos were incubated on chilled or ambient water to manipulate their developmental stage through temperature units. Once fish had absorbed their egg sacs, they were populated into outdoor 3 ft tanks at low density with in-tank structured designed for the Surrogate Project. Fish were sampled weekly up through early July 2023. The experiment was terminated a few weeks early due to water quality issues. After collection, fish were preserved in 10% buffered neutral formalin and then clear and stained. Fish will be visually examined under a dissecting microscope to determine onset and severity of fin damage. Samples have yet to be analyzed, results are expected to be collected by the end of 2024.

The vast majority of the fish are produced at the FPGL where Chinook are raised from eggs and this is where most research is being done on means of improving hatchery practices, in 2023 including the use of fasting and on improving diet quality. Up through the OHRC transition to AAHL in December 2023, this project additionally supported the financial contribution OSU makes to the OHRC in terms of OHRC staff salaries.

## Education and Outreach

OHRC researchers regularly present their findings at conferences and symposia, and produce high-level publications in peer-reviewed scientific journals. Those contributions can be found in Appendix 2 and at https://www.dfw.state.or.us/fish/OHRC/news.asp.

The OHRC Fall Creek facility re-opened to public visitation in May of 2022, following an extended closure in response to COVID-19 safety measures. OHRC staff led tours of the facility for several groups in 2023, including a large homeschool group, Crane Union High School, and an adult activities group, as well as other school groups. The OHRC also hosted a Free Fishing Day in June, assisted Alsea Fish Hatchery with their Outdoor School Forest Camp, attended the Newport Arbor Day Celebration, and hosted the ODFW Aquatic Inventories group and the Oregon Coast Aquarium Education staff. OHRC staff also maintained the center's outdoor kiosk with OHRC information and ODFW regulations, and taught students about fish anatomy and the salmon lifecycle through dissections and spawning observations.

In October of 2023, Dr. Seth White gave a guest presentation to the Oregon Angler's Alliance on using byproducts from a local brewery (Rogue Ales) to investigate olfactory imprinting to reduce straying of hatchery salmon.

Also in 2023 the OHRC was featured in several media outlets including Nautilus, The Oregonian, Hakai Magazine, Smithsonian Magazine, Popular Science, Outdoors, Sierra, The Atlantic, Food & Wine, OSU's newspaper The Barometer, and on social media via Instagram.

In late 2023, Dr. Seth White and Ashley Sanders began planning for a short film documenting issues related the OHRC mission in collaboration with Freshwaters Illustrated, an award winning, non-profit film organization based in Corvallis that specializes in aquatic science and

conservation. The goal is to reach a broader audience on a new platform, and potentially initiate a series of videos to keep the public updated with OHRC activities as they change through time.

Kathleen O'Malley developed a SFGL exhibit for the 2023 HMSC Marine Science Day. There were 1655 visitors at the exhibit to learn about state fish genetics research. She was also a guest speaker for NOAA Fisheries 2023 In Fish Career Development Summer Internship Program on July 19.

# Funding of OHRC Operations and Activities

## Operations, Education, and Outreach Funding

ODFW's 2023-2025 facilities budget for the OHRC is approximately $800,000, with approximately $600,000 of that for personnel. Funding for facilities this biennium is split out between several locations because the Fall Creek facility was closed in November 2023 due to on-going issues associated with an active landslide upstream of the site that affected water quality, the ability to maintain live fish and conduct research, and human safety. Given this, the physical location of the OHRC was relocated at that time to the Aquatic Animal Health Lab (AAHL), which is part of OSU and located just outside of Corvallis. Of the $800,000, approximately $350,000 was and will be used for the Fall Creek site, which is being minimally maintained so it does not fall into disrepair and can be used in the future if/as solutions around water quality and the landslide become available. Approximately $450,000 has been provided to OSU for the use and research associated with OHRC work at AAHL. Note that all of these facility funds are from ODFW's base License funding, and do not come from the dedicated account established for OHRC research.

## Research Funding

A dedicated *Oregon Hatchery Research Center Fund* was established by the Legislature in 2015 (Oregon Laws 2015, Chapter 734). This funding began accruing on January 1, 2016 and comes from recreational and commercial fishing surcharges and ad valorem fees, respectively, that go to ODFW. ODFW expends these funds on research projects recommended by the OHRC Board, which are described in other sections of this report. Through the end of 2023, this fund has generated over $4.4 million in revenue for research funding, which is approximately $500,000 per year and $1 million per biennium. The amount of research funding available each biennium is based on unspent revenue that has already been received, previously obligated contract amounts, and additional revenue projections through the end of the biennium that are done by ODFW's economists. For the 2023-25 biennium, it is expected that, consistent with previous biennia, approximately $1 million will be available for OHRC Research.

All research budgets are formally approved through OSU-ODFW Intergovernmental Agreements and associated sub-awards. Research conducted at and through the OHRC is supported not only by the OHRC Dedicated Research Fund, but also by extramural funding. For example, the U.S. Army Corps of Engineers awarded Drs. Noakes & Schreck $810,000 per year to carry out the Wild Surrogate Project through the OHRC, and that extramurally supported work is ongoing.

# Acknowledgements

A draft of this report was prepared for the OHRC Board by Dr. Seth White and Ashley Sanders, with project or operationally specific contributions from OHRC Facilities Manager Jen Krajcik, research assistant Michelle Scanlan, as well as Drs. Michael Banks, Michael Blouin, Andrew Dittman, Kathleen O'Malley, Claire Couch, Aimee Reed, Andy Pierce, Kelly Biedenweg, and Jessica Miller.

# Appendix 1: Detailed Activity Reports for Research Projects

A variety of research projects were conducted at or by affiliates of the OHRC in 2023. Brief summaries of research can be found in the *OHRC Activities in 2023* section above. More information about selected projects pertinent to achieving the OHRC's Mission and Goals is described below.

## Wild-like Mate Choice

Briefly, activities in testing wild-like mate choice to improve survival of hatchery fish in 2023 included, sampling returns, extracting DNA, developing libraries, genotyping samples, analyzing results at signature observation points, sharing results at scientific/public meetings, participating with the coho spawn at Sandy Hatchery, engaging partnerships to further develop our sampling innovation named VALUE TAGGER, and, grant writing. This long-term project is about 2/3 mature with current results including complete analysis of 1,293 jacks sampled in 2021 (2019 spawn offspring), 2,906 adults from the 2019 spawn, and 342 jacks from the 2020 spawn. We are also currently working through results for ~4,000 adult from the 2020 spawn, and an additional ~1,000 adults from the 2019 spawn.

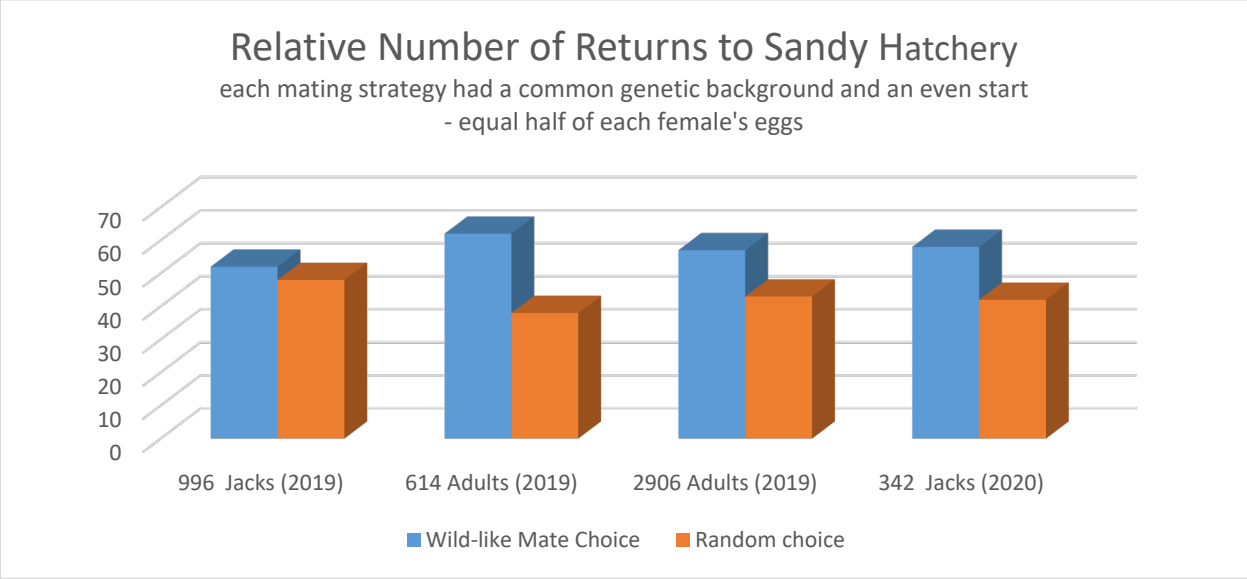



Figure 1 demonstrates overall survival advantage of wild-like mate choice partnering for each and ALL of four signature observation points we have looked at to date.

These results have been presented at the Oregon Chapter (February) and National (August) meeting of the American Fisheries Society, and two meetings of the Oregon Hatchery Research Center Board.

Grant writing was focused on seeking support to further the development of VALUE TAGGER and included an invited pitch to an *IMPACT* fund and panel of investors coordinated by OSU's Advantage Program. Unfortunately we were outcompeted by a desalinization innovation that offers tremendous gains through repurposing wastes to satisfy critical element shortfalls in the electronics industry. Our second grant effort is also to a highly competitive 'Partnership For Innovation – Research Track' offered by the National Science Foundation. VALUE TAGGER was chosen as top candidate for the single opportunity available for OSU and this proposal is currently pending in review. Herewith the executive summary to provide insight into motivation and innovation details:

**Overview:**

This PFI-RP will transform the efficiency of tagging used in the fishery industry to enable productive harvest and management in synchrony with changing conditions in near-real-time. We will achieve this by seamless integration of DNA, coded-wire-tag (CWT), species, sex, length, weight and condition sampling for 1,000s of individual fish that pass through industry each day. Initial application and target markets include managers at salmon hatcheries, landing ports, processing facilities through to guarantee of sustainability in local and international markets. Despite a $31 billion market value forecast for 2030[1], many salmon stocks are decreasing markedly across the globe. Yet vibrant salmon celebrate healthy freshwater, forest, ocean, and community ecosystems for all. In order to advance salmon futures we need to better understand which stocks are most impacted by changing conditions, identify different growth opportunities and enable new practices that prosper vital futures, despite change. Because of the fascinating life history diversity that has evolved among species of salmon (stocks), and it is clear that different stocks are responding to new conditions in different ways[2], more efficient (near-real-time) techniques to discriminate among stocks are needed so that harvest and management can respond to changes within time frames when impacts are most effective (within season). Our VALUE TAGGER innovates technology to enable CWT detection and extraction alongside fin-clip sampling and use machine learning to determine species, sex, length, weight, and condition of several 1,000 fish per day.

**Intellectual Merit:**

Fishery, management, and market needs for discrimination among salmon stocks of today are principally met through Northwest Marine Technology's (NMT) marking and reading tools that use coded-wire-tags (CWTs)[3]. The fishery has enjoyed many positive outcomes from application of CWTs which is reflected by the fact that CWT in association with Genetic Stock Identification (GSI) and other analysis tools have become gold standards applied across the west coast and globally for over 50 years[4]. VALUE TAGGER proposes to complement this CWT enterprise with efficiency and increased information through application of robotics and AI to simultaneously sample and archive: tissue/DNA, CWT, species, sex, length, weight and condition from 1,000s of individual fish per day. Advances include: 1. All the merits of established use of CWT data as well as a digital phenotypic data for each fish (currently attained manually, as possible). 2. In addition, tissue/DNA samples enable Parent Based Tagging (PBT), a technique that identifies all fish, not just those that may have CWTs, because DNA from just 2 parents tag all 3-5,000 of their offspring. 3. Further

because PBT sampling of parents tags all offspring hands and cost free, the technique can be extended to non-hatchery natural populations. 4. DNA/PBT samples can be taken non-lethally enabling a) tracing of families/heritability across generations, b) stock-specific analysis of test fisheries, c) monitoring genetic diversity, and d) cross generation tests of new breeding strategies to improve fitness and survival[5]. 5. Increased efficiency of information provision for both CWT and PBT further enables within season harvest and management responses. Working across three states and associated fishery ports in collaboration with 3 Industry Partners allows us to direct and test product development to better match user needs including partakers in fisheries, salmon hatcheries, state and federal salmon management, and other interests of the public. Current prototype II has sampled fin-snips from coho salmon, leaving efficiency and application of computer vision as the primary hurdles to be overcome in order to: 1) process several 1,000 adult salmon a day, 2) process images to enable computer vision to determine species, sex, length, weight, and, condition, of each individual sample, and, 3) integrate code that coordinates all functions in order to collate and archive data for each sample individually.

**Broader Impacts:**

Efficient, high fidelity identity tracking will ensure that natural source food practices remain sustainable and bolster resilience allowing communities to thrive through changing climate, oceans, and economies. Commercial gains attained for the salmon industry will set example applicable to other fisheries and livestock industries. This project will broaden participation and access of underrepresented students by engaging with several strategic NSF funded training programs and immersive virtual experience platforms (REU, RAPID, RCN-UBE) and transdisciplinary educational goals to foster lessons and findings from NRT and REU experience including: 1) Creation of diverse learning environments where different cultures, expertise, disciplines are held key values necessary to attain most fitting outcomes that are inclusive of broad social-environmental needs, and, 2) Professional training in communication and how to successfully use alternative working structures to best nurture and attain project goals.

## Fish Gut Microbiome

In 2023, Dr. Couch completed and published a paper and advanced several other projects that were relevant to the OHRC mission and made significant progress on her work that is funded by the OHRC. These projects are summarized briefly below.

First, Dr. Couch and colleagues completed and published a study that identified potential biomarkers of stress and immunosuppression in Chinook Salmon. These biomarkers are gut microbes that become more abundant (or less abundant) in fish that are chronically stressed, and some predict mortality in stressed or senescent fish (Couch et al. 2023). In a separate study conducted in collaboration with researchers at University of New Mexico, Dr. Couch contributed to describing the brain microbiome of juvenile and adult Chinook Salmon. In this paper, which is in review and currently available as a pre-print (Mani et al. in review), it was found that salmonids harbor a resident brain microbiome, and that this microbiome becomes dysregulated in Chinook Salmon as they reach sexual maturity and reproductive death. Research on the brain microbiome is still in its earliest stages, so we do not yet know how these changes to the brain microbiome are related to management-relevant outcomes. However, these two studies contribute significantly to

our understanding of how stress and senescence physiology relate to the microbiome and may ultimately result in new biomarkers to monitor population health or probiotics to improve survival and health outcomes in hatcheries. Developing tractable tools to monitor and manage stress and immunosuppression via the microbiome could significantly reduce costs and enhance the effectiveness of fish health programs, thus contributing to the OHRC goal of defining the factors that contribute to hatchery risk.

Previous studies by Dr. Couch and others (Couch et al. 2022a, Couch et al. 2022b, Nervino et al. 2024) identified important relationships between stress hormones, disease, intestinal health, and pre-spawning mortality in Chinook Salmon. Taken together, these studies identified associations between gut disease, microbial dysbiosis, and pre-spawning mortality using a combination of field and laboratory studies. However, causal relationships among these variables remain poorly understood. In 2023, Dr. Couch collaborated with Dr. Mike Kent and Dr. Tamsen Polley at OSU to follow up on their previous work and identify causes and mechanisms of pre-spawning mortality. To achieve this, we treated juvenile fish with different corticosteroid stress hormones and/or exposed them to gut microbes from senescent fish, then measured the effects of these treatments on intestinal disease and mortality. Data from this study is still being analyzed, but preliminary evidence indicates that a combination of stress hormones and an unknown transmissible agent contribute to morbidity and gut disease in Chinook Salmon. We are currently working to identify the transmissible agent associated with this disease and will then carry out population-level studies to determine if this agent associates with pre-spawning mortality in wild and hatchery populations of Chinook Salmon in the Pacific Northwest.

Finally, significant progress was made on Dr. Couch's OHRC-funded research project. This project, which was funded in 2022, seeks to define the effects of diet on gut microbiome communities in captive-reared fish. For this experiment, we held juvenile Chinook Salmon on two different diets: (1) a standard hatchery diet, or (2) a low-lipid diet designed for wild-like growth and development. We reared fish for eight weeks on either of these two diets, with a subset of fish switching between diets midway through the study. We collected fecal samples biweekly throughout the study and collected tissue and blood samples for immune assays at the end of the study. We have completed processing, sequencing, and preliminary analysis of the microbiome samples. Initial analysis of the microbiome data indicate that diet significantly alters the gut microbiome, and that a low-lipid diet results in a gut microbiome that is more similar to wild fish than the standard hatchery diet. Preliminary results of an innate immune assay indicates that the activity of innate immune effector proteins increases with fish size and may be indirectly related to diet. High-throughput RNA sequencing of head kidney tissues from a

subset of fish on each diet suggest that the high lipid diet increases the expression of genes associated with stress, smoltification, and immune function. Currently, we are conducting a series of studies to directly assess the effects of diet on disease resistance by experimentally infecting fish reared on different diets. These studies will clarify whether any microbiome/immune differences associated with feed type are sufficient to significantly alter disease susceptibility. If additional funding is acquired, future studies will assess the effects of other important rearing parameters (e.g. density, tank design, probiotic/antibiotic treatment) on microbiome communities, immune function, and disease susceptibility in Pacific salmon. Ultimately, results from Dr. Couch's ongoing work could contribute significantly to optimizing post-release survival of hatchery fish and reducing the risk of hatchery operations (including disease transmission) to wild fish.

Couch, C. E., Colvin, M. E., Chitwood, R. L., Peterson, J. T., & Schreck, C. B. (2022). Scope of the cortisol stress response in Chinook salmon during maturation. *Fisheries Research*, *254*, 106416.

Couch, C. E., Kent, M. L., Weiss, L. M., Takvorian, P. M., Nervino, S., Cummins, L., & Sanders, J. L. (2022). Enterocytozoon schreckii n. sp. infects the enterocytes of adult chinook salmon (Oncorhynchus tshawytscha) and may be a sentinel of immunosenescence. *Msphere*, *7*(1), e00908-21.

Nervino, S., Polley, T., Peterson, J. T., Schreck, C. B., Kent, M. L., & Alexander, J. D. (2022). Intestinal lesions and parasites associated with senescence and prespawn mortality in Chinook Salmon (Oncorhynchus tshawytscha). *Journal of Fish Diseases*.

## Timing of Release

**Klaskanine Hatchery (Select Area Bright, SABs)**

CONTACTS: Ross Mcdorman and Marc Cohen

Adults collected at hatchery and held for spawning October to November

CURRENT: 1M fish, 30 fpp at release, mid-July release date, all LV clip, 50K ad clip & CWT

**NEW: 30K fish - all CWT, June release date, ~75 fpp at release, unique tag code**

**Trask Hatchery**

CONTACTS: Ryan Fenwick and Robert Bradley

Adults collected at hatchery from August to January

Peak spawn in late November, fish spawned throughout the run.

100+ broodstock pairs

CURRENT: 150K fish, 19 to 30 ffp at release, 30K CWT, in-river volitional, August release date

**NEW: 30K fish - all CWT, 75 fpp at release, late June release date, unique tag code**

**Coos System**

CONTACTS: Gary Vonderohe and Morgan Davies (district)

CONTACTS: Dave Pease and Mitch Semrow (Coles)

Adults arrive October to December

Peak spawn in mid-November, 30% wild broodstock

Broodstock collected at Morgan and Noble Creek STEP and W. Fork Millicoma Interpretive Center

1600 adult fish = broodstock goal

CURRENT and **NEW** **(**see figure below**)**:

1. 30k tagged at Bandon and released in Morgan Cr

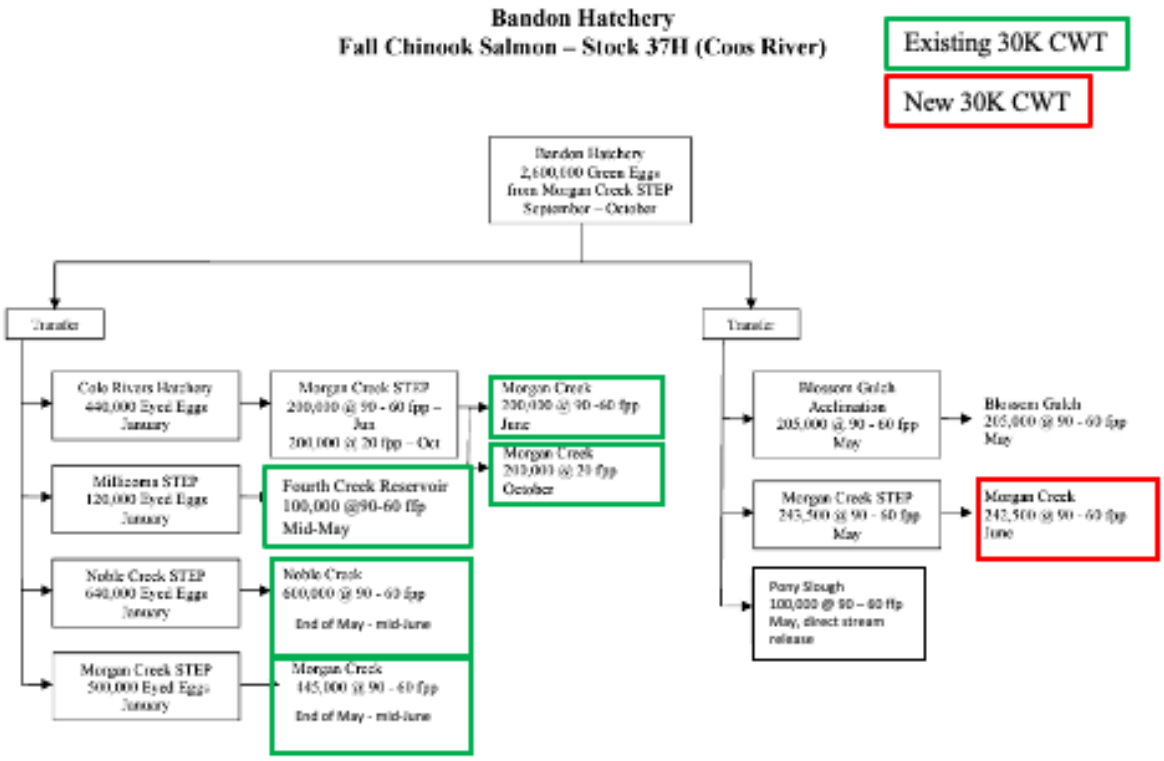
2. 30k tagged at Millicoma and released at Millicoma*

3. 30k tagged at Noble Creek and released at Noble Creek

4. 30k tagged at Morgan Creek and released at Morgan Creek (June)

5. 30k tagged at Cole Rivers and released at Morgan Cr (Oct)

6. **NEW 30k tagged at Cole Rivers and released at Morgan Cr (June) (releases have occurred in past but without CWT)**




*In 2023, the fish reared at Millicoma and are now releasing those fish (with the 30K CWT group) into 4th Creek Reservoir, which is owned by Coquille Indian Tribe.

**Elk Hatchery**

Adults arrive at trap October to January

Peak spawn in late December

Broodstock collected throughout the run.

CURRENT: 255K fish, 12 fpp at release, mid-September to mid-November (all CWT)

20K, 5 ffp, early March (all CWT)

All in-river releases

**NO NEW RELEASES OR CWTs BUT WILL BE INCLUDED IN COMPARISONS WITH OTHER RELEASES**

We have also begun to collate information on prior CWT releases from these systems for a longer-term analysis.

**Original Objectives**

***Objective 1 – Design rearing strategies for subyearling and yearling releases.***

During the initial phases of our work, we will coordinate with ODFW hatchery and facilities managers to develop plans for the spawning, rearing, tagging, and release of study fish. During our conversations with ODFW Fish Propagation staff, we identified the Klaskinine, Trask, Coos and Elk rivers as appropriate sites for our study.

***Objective 2 – Collect data for tagged release groups.***

We will coordinate with ODFW staff to develop marking and tagging plans that consider availability of tagging crews, hatchery production plans, budget, and number of tags needed based on statistical power analysis. Our preliminary analyses of statistical power suggest that, given observed mean SARs of 2.5% for coastal Oregon hatchery fall Chinook (RMIS, unpublished data), we can expect to detect a 15% or greater difference in survivorship among release groups with 30,000 tagged individuals per group, as we have proposed. We will collate existing information on juvenile size and condition and work to supplement that information, i.e., collect additional information on body condition of fish across groups prior to release.

***Objective 3 – Collect and analyze data from CWT recoveries.***

Following release of study groups, we will regularly query the Regional Mark Information System (RMIS) database for recoveries of our tagged fish. RMIS is a centralized, open-access database that stores CWT data collected from diverse sources along the west coast of North America. We expect most tag recoveries will come from ODFW hatcheries that collect returning adults, but also from fisheries, spawning grounds, and research efforts within and beyond Oregon. Beyond survivorship analyses (i.e. SARs), we will also evaluate how various juvenile release strategies affect the quality of adult hatchery salmon, including comparisons of size and age at return, timing of return to freshwater, and distribution of adult returns (i.e. homing fidelity), pending support and availability of data.

In the first year, we will determine the extent to which diet or temperature modifications in these hatcheries would be feasible for the second year of the project. We also plan to seek, and hopefully secure, funding to further examine juvenile migration patterns and growth rates using otolith structure and microchemistry analyses of returning adults, providing additional information to ODFW managers.

The Blouin lab's working hypothesis is that hatcheries inadvertently select for extreme values of heritable physiological or behavioral traits that allow some fish to grow quickly in the unnatural conditions of a hatchery (Blouin et al., 2021). This is because the size of hatchery smolts at release is positively correlated with their probability of survival at sea (e.g. Thompson et al., 2018). So there is strong selection to grow as quickly as possible in the hatchery. If those heritable, hatchery-favored traits are disfavored in the wild, then the wild-born offspring of hatchery fish that spawn in the wild would have low survival. This mechanism would explain why researchers consistently measure low fitness in hatchery fish that spawn in the wild.

Dr. Blouin's group has tested various modifications to standard hatchery practice that might reduce the variation size at release. If that could be achieved, then there would be less intense selection on size at release, and a lower rate of domestication. The researchers have tested various manipulations of the hatchery environment that they predicted would favor the fish that don't normally thrive in the standard environment. For example, they tested varying the fat content of food to make it more like the high-protein wild diet, with the idea that perhaps the ability to process high-fat food was under selection (Blouin et al., 2021). Another hypothesis is that fish that thrive and grow quickly in the hatchery are more aggressive and feed more boldly. In the wild that behavior exposes them to predation, but in the hatchery there is no cost to such behavior. Therefore, extreme boldness may be favored under hatchery conditions, but not under wild conditions (Thompson and Blouin, 2016; Wrey et al., 2020). Manipulations designed to favor the "shyer", more skittish juveniles they have tried included lowering the density of fish (Thompson and Blouin, 2015), and changing the timing and method of food delivery (unpub data). However, none of these treatments appreciably lowered the variance in body size.

For the 2022-2023 growing season they set up three experiments. In the first experiment they added physical structures in the tanks to give shyer fish places to hide from the more aggressive fish. The researchers hypothesized that this shelter may encourage the shyer fish to feed more readily, and so grow more quickly. The second experiment used circulating water in the tanks to make all the fish swim constantly. This should prevent dominant fish from setting up territories, again releasing the subdominant fish from aggression. Thirdly, they tested the effect of grading fish by size partway through the growth period, and then raising the small ones separately (with more food and space, to see if they would catch up to the big ones).

Neither adding physical structures to the tanks nor making the fish swim constantly had an appreciable effect on the variance among families or on the on the total variance among fish in body size. There was a slight effect in the predicted direction, but not strong enough to warrant retesting the treatment on a production scale. As in previous studies, they also observed a very strong family effect in which the families that grew the largest in one environment grew the largest in others, and vice versa. Thus, they concluded after these last experiments that simple manipulations of the hatchery environment (of the type that would be practical to apply in hatcheries) are unable to overcome what appears to be very strong family effects.

The one experiment that did give interesting results was when the researchers graded fish into three size groups (small, medium and large) about of third of the way through the growth period, and then raised each group under different conditions. They raised the initially-small fish at very low density and with extra food, the initially-medium fish under standard conditions, and the initially-large fish at high density and with reduced food. The idea was that releasing the initially-small fish from competition with larger fish would allow them to "catch up". That plus holding back the initially-larger fish should compress the size distribution on both tails so that the final variance in size would be much smaller than that in the control (ungraded) tanks.

At the end of the experiment, researchers found that after pooling the small, medium and large groups together and comparing that graded cohort to the cohort of fish grown in control tanks, the graded cohort did indeed have a significantly smaller variance in fish size. However, this reduction resulted only from holding back the growth of the initially-large fish. The initially-small fish never caught up, despite having been raised in very favorable conditions (fig. 1).

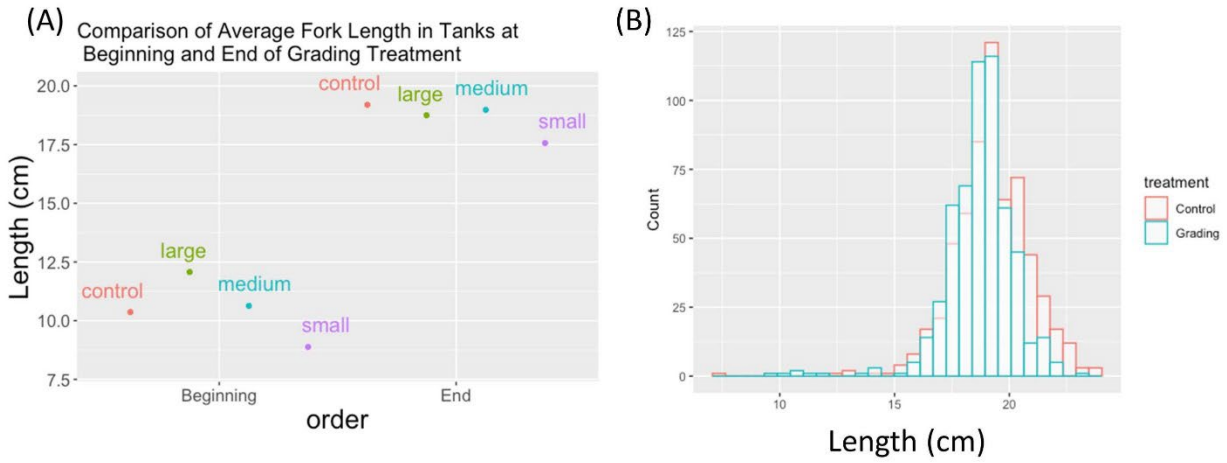


Figure 1. (A) Average size of fish in each treatment group at the beginning and end of the experiment. “Beginning” shows the sizes of each group right after grading, while “End” shows the size of each group at the end of the 1-year grow-out period. Control = the control tanks (raised under standard conditions); “small”, “medium” and “large” are the three grading treatment groups. (B) Total distribution of size among fish in each cohort (graded or control). Notice that in the graded cohort the right hand tail of the distribution is pulled in substantially relative to controls, but the left hand tail is basically unchanged.

From this result, the researchers conclude that the variation in size among fish at release is not just a result of behavioral interactions among bold vs shy, or aggressive vs. passive fish, but probably involves inherent variation among individuals in their ability to thrive in the novel environment of a hatchery (i.e. some physiological or behavioral limitation that isn’t about the other fish in the tank). The researchers hypothesize that those initially-slow-growing fish might be slow growing no matter what conditions they are offered in the hatchery, and will be eventually be selected out after release. As the distribution of families among the three grading groups was very non-random, the researchers conclude that there would likely still be some response to selection among families if such a graded cohort were released into the wild.

*Final conclusions:*

At the end of several years of testing various manipulations to the hatchery environment, the researchers conclude that although grading shows some promise, simple alterations to the hatchery environment (changing density, feed type, feeding schedule, feeding methods, adding physical structures, increasing water flow), are not likely to change the opportunity for selection on size at release enough to warrant the disruption to standard hatchery protocols. Furthermore, most alterations one could make to standard practice are likely to reduce the overall productivity of the hatchery. While in some situations that decrease might be warranted in order to prioritize the production of a more wild-like fish, the simple environmental manipulations tested here seem unlikely to reduce the opportunity for domestication enough to make that tradeoff worthwhile.

In summary, selection on size at release is thought to be responsible for the rapid domestication that occurs when salmon are raised in hatcheries. Blouin and colleagues have tested whether a variety of manipulations to the hatchery environment could be used to appreciably reduce the opportunity for selection on size at release. They conclude that the very strong family effects are not easily overcome by alterations to hatchery practice that would be reasonably feasible. They suggest that any future research on how to reduce the rate of domestication should focus more on identifying the physiological or

behavioral traits that determine why some fish thrive in a hatchery setting while others do not.

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### Olfactory Imprinting

Three central hypotheses are being tested in this project.

1. First, it is hypothesized that the inability of salmon to effectively distinguish the olfactory cues of the hatchery from the river water that supplies the hatchery results in elevated levels of in-river straying.

To address this issue, this project tests the idea that Chinook Salmon exposed to a unique bouquet of chemical odorants during select juvenile stages will home back to their natal hatchery (as adults) at higher rates than control fish (not exposed as juveniles), when the same chemicals are added to water leading into the hatchery (i.e. adult fishway). For practical purposes, candidate odorants should be neither innately attractive or repulsive to salmon, detectable, imprintable (i.e. learnable), safe and legal to add to hatchery water that enters the Elk River, and relatively inexpensive. Based on the results of these studies (May et al. in prep, Kamran et al. in prep), a cocktail of amino acids (L-arginine, L-threonine, L-glutamic acid) was determined to be the best candidate odors for scenting the hatchery water to improve imprinting. Extensive water chemistry analysis of hatchery and river water demonstrated that the addition of these amino acids would successfully alter the odor signature emanating from the hatchery (Dittman et al. manuscript in prep).

Beginning in 2020, Chinook Salmon were exposed to an amino acid cocktail during embryonic incubation (Jan.-March), and during the parr-smolt transformation (May June) and just prior to release (Sept-Oct.). All groups were given treatment- and raceway-specific coded wire tags and released into the Elk River in October 2020. This treatment and release design was repeated during 2021 and 2022. The first group of returning adults from this experiment returned to the Elk River hatchery in fall 2021 and in anticipation of these returning fish, an odor delivery system was established at the Elk River Hatchery adult return ladder and amino acid cocktails were constantly metered in the ladder during the entire adult return period Nov. 1, to Jan. 31 during the 2021-2022, 2022-2023, and 2023-2024 return years. Coded wire tags recovered from 2021-2022 and 2022-2023 spawning ground and creel surveys have been decoded and initial analyses of these tags has been initiated. Finally, water samples have been collected within and downstream from the hatchery to validate the amino exposure levels during experiments in 2022-2023.

To date, all odor exposures, deliveries, and sample collections were completed as scheduled. The final juvenile exposure was completed in 2022 and adult returns will be monitored for the next several years as experimental fish return and while amino acids are delivered to the ladder.

**Highlights of 2023**

**Elk River hatchery (ERH) odor experiment:** Multi-year experiment to test whether Chinook salmon exposed to a unique bouquet of chemical odorants during select juvenile stages will demonstrate higher homing fidelity to their natal hatchery (as adults) than control fish (not exposed as juveniles), when the same chemicals are added to water leading into the hatchery (i.e. adult fishway). This experiment was initiated in 2020 and will continue until 2026.

**Jan-Feb:** Completed the 3rd year of our amino acid odor deliveries at the ERH adult return ladder and collection of experimental salmon returning to the Elk River. During the 2023-2024 return year, 1245 experimental salmon were recovered at the hatchery, 192 were recovered in the sport fishery, and 50 were recovered on the spawning grounds. Collected water samples for AA analysis.

**Jan-May:** Initiated experiments to test the efficacy of additional complex, less-expensive imprinting odor solutions and to develop molecular markers of imprinting that will facilitate future assessments of imprinting success. Created experimental crosses and transported fish from the ERH to OHRC for testing. Odors tested included Ecohume, beer brewing byproducts, cyprinid odors, algal cultures and macroalgae, supplement grade amino acids, and population- and tributary-specific odors. Specifically we conducted EOG experiments to assess the olfactory ability of salmon to detect these odors and Y-maze experiments to examine innate behavioral responses to odors. Analyses of these data will be completed in 2024. A subset of salmon were exposed to test odors to establish protocols for gene expression studies to identify genes linked to the imprinting process.

**Oct 2023-Feb 2024:** Despite a large wild fire in the Elk River Basin, that burned within meters of the hatchery, we successfully initiated and maintained the amino acid odor delivery to the ERH ladder and completed recovery of adult spawners for the 4th year of the experiment. Collected water samples for AA analysis.

2. The second hypothesis tested under this project is that rearing of salmon embryos in river water may be beneficial for improving olfactory development and homing fidelity. In most hatcheries, including the Elk River Hatchery, salmon are reared during embryonic stages in well water to minimize exposure to pathogens and control development rates. However, early studies at the OHRC demonstrated that salmon actively avoid well water and that olfactory development is altered in well water-reared fish (Dittman et al 2015). To test whether embryonic rearing water influences successful imprinting, we initiated a two-broodyear study in 2017 at the Elk River Hatchery, wherein embryos were incubated in either Elk River water or well water (per conventional hatchery practice). In June of their first year, juveniles were given treatment- and raceway-specific coded wire tags and released in the fall. Adults from these studies were recovered at the hatchery ladder and spawning grounds in 2019-2022 with the final experimental fish returning Fall 2023. The final returning experimental fish have been recovered at the ERH and Elk River spawning grounds. Coded wire tags will be decoded in 2024 and improvements in homing fidelity will be assessed by comparing differences in hatchery returns between the well water and river water exposure groups. Two manuscripts describing the results and management implications of this study will be completed in 2024-2025.

3. Finally, the third hypothesis tested under this project is that the timing of odor exposure and release may be critical for successful olfactory imprinting. Wild Elk River Chinook Salmon typically migrate to sea in the late spring of their first year and the timing of olfactory imprinting is likely linked to these migratory events. In an effort to minimize ecological interactions between wild and hatchery fish and to improve hatchery fish survival, juvenile salmon are released from Elk River Hatchery much later than wild fish typically migrate seaward. However, this practice might impact successful imprinting and increase the rate of straying by adult hatchery salmon. As part of this project, we assessed imprint timing in Elk River Hatchery salmon by measuring several physiological and endocrine metrics associated with smolting and imprint timing. Laboratory analyses of these samples was completed in 2021 and suggest that two important periods for odor exposure are late spring and just prior to release. These findings have been incorporated into odor exposure experiments and final reports and publications on this work (Dittman et al. in prep) will be submitted in 2024.

# Appendix 2: Impact of Research

Findings from research conducted at and through the OHRC are disseminated through peer-reviewed publications, technical reports, as well as presentations at conferences and symposia. Management applications of OHRC research are discussed in a previous section of this report. Listed here are papers, reports, and presentations developed by OHRC-supported researchers. **Works completed or submitted in 2023 are indicated in bold**:

## Technical Reports, Theses, and Peer-reviewed Journal Publications


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Bellinger, M.R., Wei, J., Hartmann, U., Cadiou, H., Winklhofer, M., and M.A. Banks. 2022. Conservation of magnetite biomineralization genes in all domains of life and implications for magnetic sensing. *Proceedings of the National Academy of Sciences* 119 (3) e2108655119; https://doi.org/10.1073/pnas.2108655119.

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Vaux, F., Bohn, S., Hyde, J.R., and K.G. O'Malley. 2021. Adaptive markers distinguish North and South Pacific Albacore amid low population differentiation. *Evolutionary Applications*. https://doi.org/10.1111/eva.13202

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**White, S.M., Dittman, A.H., Johnson, M.A., and T.P. Quinn. In review. Climate-driven straying dynamics in anadromous salmon and steelhead: Research agenda for conservation. *Ecology of Freshwater Fish.***

Whitmore, M., Richardson, S., Huff, A., Goodson, K., Quinn, T.P., Dittman, A.H., Johnson, M.A., Kamran, M., and D.L.G Noakes. 2021. Homeward bound: In-river movements of adult hatchery-and natural-origin Chinook Salmon in the Elk River, Oregon. *North American Journal of Fisheries Management* 41(4): 1088-1096.

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## Presentations at Research Conferences and Meetings

Auld, H.L., Jacobson, D.P, Rhodes, A.C., and M.A. Banks. 2019. Mate choice of hatchery and wild coho salmon. Behaviour. Chicago, IL.

Auld, H.L., Jacobson, D.P., Rhodes, A.C., and M.A. Banks. 2019. Mate choice of hatchery and wild coho salmon. Oregon Chapter of the American Fisheries Society. Bend, OR.

Auld, H.L., Jacobson, D.P, and M.A. Banks. 2019. Mate choice of hatchery and wild coho salmon. Canadian Conference for Fisheries Research. London, Ontario, Canada.

**Banks, M. 2023. VALUE TAGGING 1,000s of Salmon. Invited Pitch to UVDF Impact Fund Investor Panel, OSU Advantage Innovation Impact Program.**

**Banks, M., Auld, H., Jacobson, D., Kumar, R., Tanenholtz, S., Wengrove, D., Baker, C., and R. Queen. 2023. VALUE TAGGING 1,000s of 'wild-like' hatchery salmon to**

**test innovations and improve the vitality of hatcheries. Oral presentation. Oregon Chapter of the American Fisheries Society Annual Meeting. Eugene, OR.**

**Banks, M., Auld, H., Jacobson, D., Kumar, R., Tanenholtz, S., Wengrove, D., Baker, C., and R. Queen. 2022. Improving return numbers by adopting breeding strategies observed more fit among wild fish: Initial evidence from a three-year experiment at Sandy Hatchery, Oregon. Oral Presentation. Northwest Fish Culture Concepts Annual Meeting. Portland, OR.**

**Banks, M., Auld, H., Jacobson, D., Kumar, R., Tanenholtz, S., Wengrove, D., Baker, C., and R. Queen. 2023. Testing 'wild-like' mating in hatcheries: an approach to reduce fitness differences compared to wild fish. Oral Presentation. National American Fisheries Society Annual Meeting. Grand Rapids, MI.**

**Banks, M., Auld, H., Jacobson, D., Kumar, R., Tanenholtz, S., Wengrove D., Baker C. and R. Queen. 2023. Testing 'wild-like' mating in hatcheries to: increase hatchery fitness and reduce impacts on wild fish. Oral Presentation. OHRC Board Meeting.**

**Banks, M., Jacobson, D., Auld, H., Kumar, R., Tanenholtz, S., Wengrove, D., Baker, C., and R. Queen. 2023. Testing 'wild-like' mating in hatcheries: an approach to reduce fitness differences compared to wild fish. Oral Presentation. OHRC Board Meeting.**

Bohn, S., Whitman, L., Cannon, B., Hart, S., Lewis, M., and K.G. O'Malley. 2019. Use of neutral and adaptive (Greb1L) genetic markers to discriminate spring and fall Chinook salmon across time and space in the Sandy River, Oregon, USA. Oral Presentation. American Fisheries Society. Reno, NV.

Cogliati, K.M., Friesen, T.A., Johnson, M.A., Olmsted, P., Schreck, C.B., and D.L.G. Noakes. 2021. Migration and survival of juvenile winter steelhead above and below high-head dams. Pacific Coast Steelhead Management Meeting. Abstract and presentation available at: https://www.psmfc.org/steelhead/past-2021.html

**Couch, C.E. 2023. The role of the microbiome in Pacific salmon health. Oregon Department of Fish and Wildlife lunchtime seminar series. Corvallis, OR.**

**Couch, C.E. 2023. Optimizing rearing conditions of Pacific salmon for hatchery production and conservation. Oregon Hatchery Research Center. Alsea, OR.**

**Couch, C.E. 2023. Big fish with tiny friends: the role of the microbiome in Pacific salmon health. Oral Presentation. Oregon Chapter of the American Fisheries Society. Eugene, OR.**

Couch, C.E. 2022. Monitoring, management, and microbes: the role of commensal bacteria in fish health. Invited lecture at the Continuing Education Session of the Western Fish Disease Workshop, Hood River, OR.

**Dayan, D.I., Fitzpatrick, C.K., Couture, R., and K.G. O'Malley. 2023. Evaluating spring Chinook salmon releases above Cougar Dam, on the South Fork McKenzie River, using genetic parentage analysis. Willamette Fisheries Science Review. Corvallis, OR.**

**Dittman, A.H., Johnson, M.A. Gertken, R. Quinn, T., and S. White 2023. Creating a Unique Odor Bouquet to Improve Homing of Hatchery-Reared Salmon. Oral Presentation. Oregon Chapter of the American Fisheries Society Annual Meeting. Eugene, OR.**

**Dittman, A.H. 2023. Imprinting salmon to targeted locations using natural odor cues: a new imprinting paradigm for hatchery programs? Oral Presentation. Alaska Chapter of the American Fisheries Society Annual Meeting. Fairbanks, AK.**

Dittman, A.H. 2022. Remembrance of things past: Strategies to reduce straying in hatchery-reared salmon. Presentation to NWFSC, NOAA.

Dittman, A.H. 2022. Olfactory imprinting and homing in Pacific salmon: Mechanisms and controlling factors. Presentation to Alaska Dept. Fish and Wildlife, University Alaska, Alaska Science Center.

Hakanson, O., Cogliati, K.M., Noakes, D.L.G., and C.B. Schreck. 2020. Conceptual decision making model for artificial rearing of fish intended for use in passage studies. OR Chapter American Fisheries Society, Bend, OR.

Herron, C. 2022. The surrogate wild fishes rearing method mitigates the stress response in juvenile Chinook salmon and steelhead trout. Oral Presentation. Northwest Fish Culture Concepts Annual Meeting. Portland, OR.

Johnson, M.A. 2022. Fishing for the next generation: the value of angler-assisted broodstock collection programs. Presentation to the ODFW Restoration and Enhancement Board. Newport, OR.

Johnson, M.A. 2022. An Introduction to the Oregon Hatchery Research Center. Presentation at the ODFW Hatchery Managers' Meeting. Elkton, OR.

Johnson, M.A. 2022. The Olfactory Imprinting Project. Presentation at the ODFW Hatchery Managers' Meeting. Elkton, OR.

Johnson, M.A. 2020. Fishing for the next generation: the value of angler-assisted broodstock collection programs. Webinar presentation to ODFW managers and staff. 2020.

Johnson, M.A. 2019. Managing genetic risk from hatchery salmon. Oral presentation at Public Outreach Event. Port Orford, OR.

Johnson, M.A., Spangler, J.J., Jones, M., Couture, R.B., and D.L.G Noakes. 2021. Can angler-caught broodstock programs improve catch rate of hatchery steelhead? Oral presentation at the Pacific Coast Steelhead Management Meeting. Abstract and presentation available at: https://www.psmfc.org/steelhead/past-2021.html

Johnson, M.A., Spangler, J.J., Couture, R.B., and D.L.G. Noakes. 2019. Can angler-caught brood improve catch rates in steelhead fisheries? Results from a genetic tagging study on Oregon's Alsea River. Oral presentation at the Annual Meeting for the Oregon Chapter of American Fisheries Society. Bend, OR.

Kamran, M. 2019. Olfactory imprinting. Oral presentation at Public Outreach Event. Port Orford, OR.

Kamran, M. 2019. Olfactory imprinting and homing in Pacific salmon. Oral presentation for the Confederated Tribes of Warm Springs at the Warm Springs National Fish Hatchery.

Kamran, M., Pollock, M.M., Dittman, A.H., Johnson, M.A, and D.L.G. Noakes. 2019. Use of olfactory learning and conditioning assays to select odorants for olfactory imprinting to improve homing in Pacific salmon. Oral Presentation at the Gordon Research Seminar, Movement Ecology of Animals. Lucca, Italy.

Kamran, M., Pollock, M.M., Dittman, A.H., Johnson, M.A, and D.L.G. Noakes. 2019. Using behavioral assays to select odorants for olfactory imprinting to improve homing in Pacific salmon. Poster Presentation. Gordon Research Conference, Movement Ecology of Animals. Lucca, Italy.

Kamran, M., Pollock, M.M., Dittman, A.H., Johnson, M.A, and D.L.G. Noakes. 2019. Smells like home: Use of behavioral assays to select odorants for olfactory imprinting to improve homing in Pacific salmon. Oral Presentation. Society of Integrative and Biology Annual meeting. Tampa, FL.

Krajcik, J. 2019. Salmon research at the Oregon Hatchery Research Center". Northwest Fish Culture Concepts Meeting. Victoria, British Columbia.

Krajcik, J. 2022. Can Hatchery Rearing Practices Influence the Onset of Fin Erosion in Steelhead Trout?. Oral Presentation. Northwest Fish Culture Concepts Annual Meeting. Portland, OR.

**Miller, J.A. and B.R. Beckman. 2023. Evaluating effects of smolt size, condition, and season of release on the quality and abundance of returning adult hatchery salmon. Oral presentation. Oregon Hatchery Research Center Board Meeting. Corvallis, OR.**

Moser, B. 2022. A Review of Methods to Reduce Warming Water in Hatcheries. Oral Presentation. Northwest Fish Culture Concepts Annual Meeting. Portland, OR.

**Obley, M. 2023. Rearing velocity influence size variation among full sibling families of steelhead (*Oncorhynchus mykiss*). Oral Presentation. Oregon Chapter of the American Fisheries Society Annual Meeting. Eugene, OR.**

**Obley, M. 2023. Modifications to rearing environments as a method for reducing domestication selection in hatchery-reared steelhead (*Oncorhynchus mykiss*). MSc thesis defense in Integrative Biology at Oregon State University. Corvallis, OR.**

O'Malley, K.G. 2020. *Greb1L* variation in Chinook salmon from the Sandy and Rogue Rivers. Genomics Workshop: Reviewing and synthesizing the state of the science regarding associations between adult run timing and specific genotypes in Chinook salmon and steelhead. NOAA Northwest Fisheries Science Center. Seattle, WA.

O'Malley, K.G., Dayan, D.I., Mazur, S., Green, L.J., Bohn, S., Johnson, M.A., Van Dyke, D.J., Samarin, P., Wells, A., and R.D. Battleson. 2022. Genetic diversity within late-summer and half-pounder steelhead (*Oncorhynchus mykiss*) in the Rogue River, Oregon. Oral Presentation. American Fisheries Society Meeting. Spokane, WA.

**O'Malley, K.G., Dayan, D.I., Sard, N.M., Johnson, M.A., Fitzpatrick, C.K., and R. Couture. 2023. A single generation in the wild increases fitness for descendants of hatchery Chinook salmon (Oncorhynchus tshawytscha). Coastwide Salmonid Genetics Meeting. Boise, ID.**

**O'Malley, K.G., Dayan, D.I., Fitzpatrick, C.K., and G.A. Grenbemer. 2023. Evaluating spring Chinook salmon releases above Detroit Dam and below Big Cliff Dam, on the North Santiam River, using genetic parentage analysis. Willamette Fisheries Science Review. Corvallis, OR.**

**Peterson, J.T. 2023 The Wild Fishes Surrogate Project: Where we have been, are, and will be. Oral Presentation. Willamette Fisheries Science Review. Corvallis, OR.**

Piotrowski, S.J., O'Malley, K.G., Hereford, M.E., Pearse, D.E., Armstrong, J.B., Tinniswood, W.R., and B.S. Ramirez. 2020. Genomic diversity of Klamath Redband Trout. Oregon American Fisheries Society Meeting. Bend, OR.

Reed, A. 2022. Thiamine supplementation improves survival and body condition of hatchery-reared steelhead (*Onchorhynchus mykiss*) in Oregon. Oral Presentation. Northwest Fish Culture Concepts Annual Meeting. Portland, OR.

**Schreck, C.B. 2023. Artificial Propagation Producing Wild-Like Salmonids. Coregonine Science Webinar Series. U.S.G.S. Great Lakes Science Center. Ann Arbor, MI.**

**White, S. et al. 2023. The Oregon Hatchery Research Center: A retrospective and forward look at sustainable hatchery management. Oregon Chapter of the American Fisheries Society Annual Meeting. Eugene, OR.**

**White, S. et al. 2023. Investigating olfactory imprinting to reduce straying in hatchery salmon. Advances in the Population Ecology of Stream-Dwelling Salmonids VI. Mallorca, Spain.**

**White et al. 2023. Advancing Hatchery Science: Lessons from the Oregon Hatchery Research Center. American Fisheries Society Annual Meeting, Grand Rapids, MI.**

**Wiley, B.C. and K.G. O'Malley. 2023. North Fork Malheur River Bull Trout (*Salvelinus confluentus*) eDNA Monitoring Project Overview & Progress. Malheur River Bull Trout Technical Advisory Committee Annual Meeting. Virtual Meeting.**


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