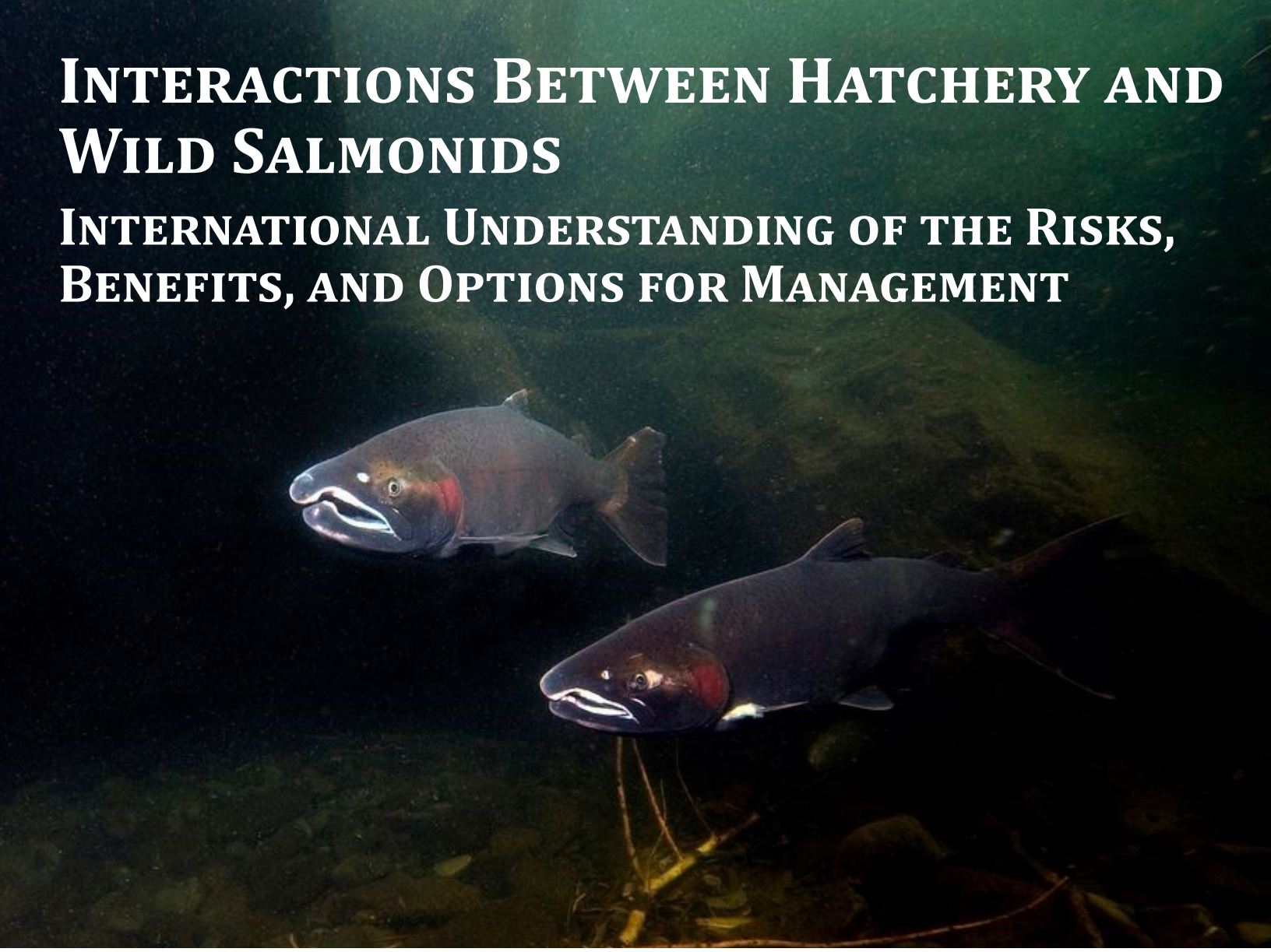
Interactions Between Hatchery and Wild Salmonids

International Understanding of the Risks, Benefits, and Options for Management



American Fisheries Society
Portland Oregon
145th Annual Meeting
August 16-20, 2015

Oregon Convention Center

Room C-124

August 17-19, 2015

INTERACTIONS BETWEEN HATCHERY AND WILD SALMONIDS
INTERNATIONAL UNDERSTANDING OF THE RISKS, BENEFITS, AND OPTIONS FOR MANAGEMENT

SYMPOSIUM DESCRIPTION

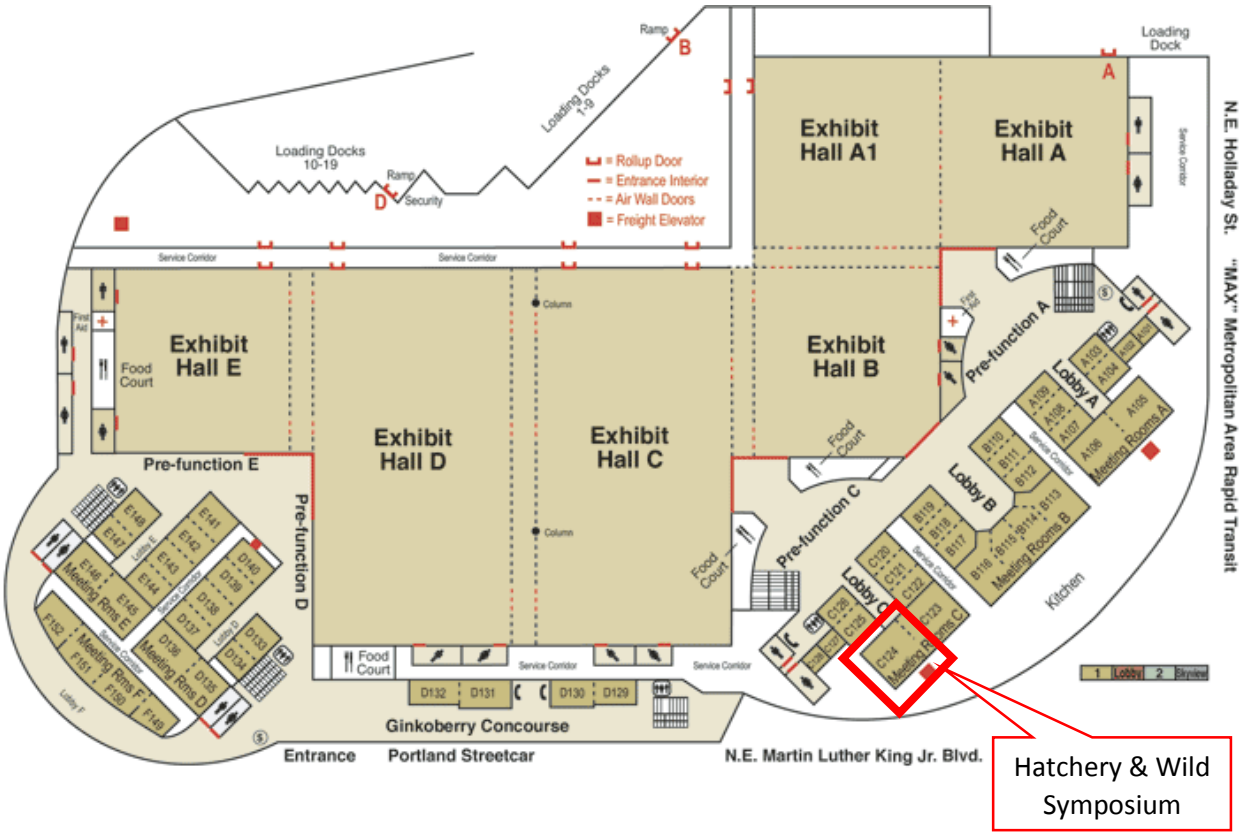
The interaction between hatchery and wild salmonids is an important and controversial topic in the Pacific Northwest and elsewhere. Widespread reduction in the abundance of natural populations occurred through the 20th century in western North America and earlier in Europe. Natural population declines have been associated with anthropogenic activities that affected the quantity and quality of habitat for spawning and juvenile rearing, increased migration mortality due to waterway impoundment, and overharvest. In response to natural population declines, fisheries management agencies instituted hatchery programs to mitigate for lost production, and more recently, to maintain or rebuild natural populations. In some fisheries, hatchery programs have had the unintended consequence of further imperiling native populations. Resource managers and researchers from North America, Europe, and South America are reevaluating how these harvest mitigation and supplementation hatchery programs are managed, and are considering the degree to which these programs may be affecting efforts to conserve or restore wild salmonid populations. As relationships between hatchery-produced fish and wild populations become better understood, there is a growing need to inform policymakers, resource managers, recreational, tribal, and commercial fishing communities, and the public on the importance of wild populations, and to define the role that hatcheries play in supporting fisheries. This session will convene fishery managers and researchers from multiple continents to discuss the role of salmonid hatcheries and how these facilities can best be used to meet dual objectives that are sometimes in conflict: the conservation of wild salmonids and harvest.

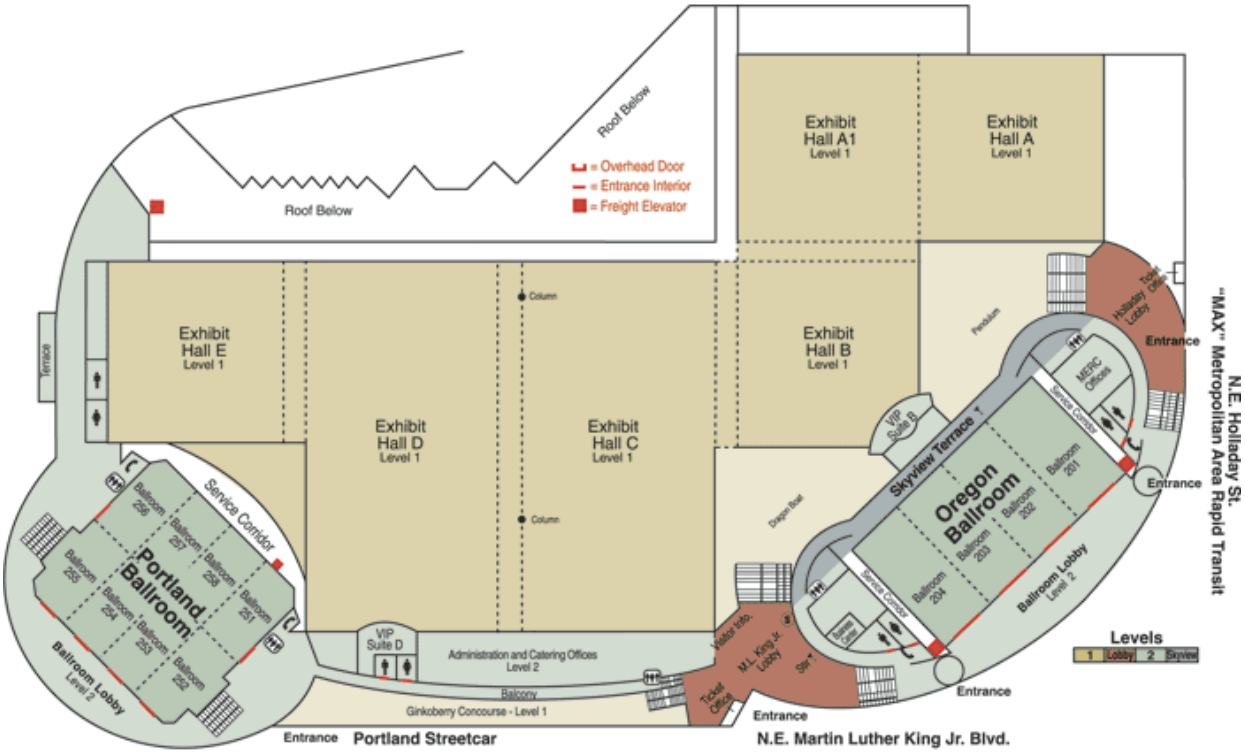
A special thanks to the symposium organizers and presenters for taking part in the symposium. The symposium was organized in part by members of the Oregon Chapter of the American Fisheries Society. We expect to have a beneficial discussion on the role of hatchery and wild fish in fisheries management and conservation. The symposium will culminate in a panel discussion on Wednesday, August 19th.

Travel grants were provided by The Fisheries Society of the British Isles in support of Nigel Milner, and by the Helge Ax:son Johnsons Foundation, Sweden in support of Anna Hagelin. Daniel Gomez Uchida is supported by Fondo de Desarrollo Científico y Tecnológico (FONDECYT 1130807), Fondo de Desarrollo de Áreas Prioritarias (FONDAP 15110027) - Interdisciplinary Center for Aquaculture Research (INCAR), and Fondo de Investigación Pesquera y Acuicultura (FIPA 2014-87).

Cover photo courtesy Oregon Department of Fish and Wildlife.

OREGON CONVENTION CENTER LAYOUT (ROOM C-124)





INTERACTIONS BETWEEN HATCHERY AND WILD SALMONIDS
INTERNATIONAL UNDERSTANDING OF THE RISKS, BENEFITS, AND OPTIONS FOR MANAGEMENT

PLANNING COMMITTEE

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INTERACTIONS BETWEEN HATCHERY AND WILD SALMONIDS
INTERNATIONAL UNDERSTANDING OF THE RISKS, BENEFITS, AND OPTIONS FOR MANAGEMENT

SYMPOSIUM SCHEDULE

MONDAY, AUGUST 17, 2015 (OREGON CONVENTION CENTER RM C-124)

PART 1A – HATCHERY REFORM: SCIENCE AND PERSPECTIVES

120 pm – 140 pm **Introductory Remarks**

140 pm – 200 pm **Don Campton,** *U.S. Fish & Wildlife Service*
Hatchery Reform: What Have We Learned and Not Learned Since 1995?

200 pm – 220 pm **Charles Huntington,** *Clearwater BioStudies*
A Broad-Scale View of Regional Hatchery Program Reform in Its Early Stages

220 pm – 240 pm **Kathryn Kostow,** *Oregon Department of Fish and Wildlife*
An Overview of Risks, Benefits and Best Management Practices in Pacific Northwest Salmon and Steelhead Hatchery Programs

240 pm – 300 pm **Nigel Milner,** *APEM Ltd, Bangor University*
A UK Perspective on Atlantic Salmon Stocking Illustrated by the River Tyne Stocking Programme

300 pm – 320 pm **Monday Afternoon Break**

PART 1B – MANAGEMENT AND POLICY

320 pm – 340 pm **Yasuyuki Miyakoshi,** *Hokkaido Research Organization*
Hatchery Programs of Chum Salmon in Hokkaido, Japan: Current Perspectives and Issues

340 pm – 400 pm **Kim K. Jones,** *Oregon Department of Fish and Wildlife*
Population Viability Improvements Following the Removal of a Hatchery Program in Salmon River (Oregon)

400 pm – 420 pm **Jesse T. Trushenski,** *Southern Illinois University Carbondale*
Introspection and Innovation: AFS and Hatcheries and Management of Aquatic Resources

420 pm – 440 pm **William Bosch,** *Yakama Nation Fisheries Program*
A Synthesis of Findings from an Integrated Hatchery Program after Three Generations of Spawning in the Natural Environment

440 pm – 500 pm **Jason Vogel,** *Nez Perce Tribe*
Conservation and Consumption: Nez Perce Tribe Duty and Obligation

500 pm – 520 pm **Ed Bowles,** *Oregon Department of Fish and Wildlife*
Oregon's Coastal Plan: A Walk on the Wild (and Hatchery) Side

TUESDAY, AUGUST 18, 2015 (OREGON CONVENTION CENTER RM C-124)

PART 2A – GENETIC EFFECTS

800 am – 820 am **Shuichi Kitada,** *Tokyo University of Marine Science and Technology*
Genetic Interactions between Hatchery and Wild Fish: Japanese Chum Salmon Perspectives

820 am – 840 am **Maureen Hess,** *Columbia River Inter-Tribal Fish Commission*
Supplementation with Local, Natural-Origin Broodstock May Minimize Negative Fitness Impacts in the Wild

840 am – 900 am **Charles Waters,** *University of Washington*
Linking Genotype and Phenotype: Identifying Fitness Traits That Respond to Genetic Adaptation to Captivity in Chinook Salmon

900 am – 920 am **Brice Adams,** *U.S. Fish & Wildlife Service*
Abernathy Creek Steelhead: Population Genetics and Reproductive Success at a Conservation Hatchery with Wild Broodstock Integration

920 am – 940 am **Marc A. Johnson,** *Oregon Department of Fish and Wildlife*
Natural Production and Genetic Introgression from Hatchery Summer Steelhead in the Upper Willamette River

940 am – 1000 am **Sewall F. Young,** *Washington Department of Fish and Wildlife*
Genomic Signatures of Domestication in Two Independently Developed Hatchery Steelhead (*Oncorhynchus mykiss*) Strains Propagated in Western Washington

1000 am – 1020 am **Tuesday Morning Break**

1020 am – 1040 am **Neil F. Thompson,** *Oregon State University*
Domestication Selection and Loss of Fitness in Hatchery Salmon and Steelhead: Possible Mechanisms for Fitness Loss

1040 am – 1100 am **Kyle C. Hanson,** *U.S. Fish & Wildlife Service*
Ecological and Genetic Effects of a Conservation Hatchery on Natural-Origin Steelhead: Lessons from a Decade-Long Study in Abernathy Creek, Washington

1100 am – 1120 am **Daniel Gomez-Uchida,** *Universidad de Concepcion*
Understanding the Colonization History of Chinook Salmon in Patagonia Using Single Nucleotide Polymorphisms (SNPs): Gauging the Effects of Artificial Vs. Natural Propagation

1120 am – 1140 am **Nick Sard,** *Oregon State University*
Maintenance of Genetic Diversity during Reintroduction: Assessment Among Potential Parents, Offspring, and Migrants at Two Spring Chinook Salmon Programs

1140 am – 1200 pm **Joe Zendt,** *Yakama Nation Fisheries Program*
Spawning Interactions Between Hatchery and Wild Steelhead and Spring Chinook Salmon in the Klickitat River, Washington: Results from Radio Telemetry and Genetic Investigations

1200 pm – 120 pm **Tuesday Lunch Break**

TUESDAY, AUGUST 18, 2015 (OREGON CONVENTION CENTER RM C-124)

PART 2B – GENETIC AND ECOLOGICAL EFFECTS

120 pm – 140 pm **Justin Bretz,** *Nez Perce Tribe*
Adaptive Management and the Nez Perce Tribal Hatchery Spring Chinook Salmon Supplementation Program

140 pm – 200 pm **Brad Cavallo,** *Cramer Fish Sciences*
The Good, the Bad and the Ugly: California Chinook Salmon and Steelhead Hatcheries and Their Apparent Influence on Wild Stocks

PART 2C – ECOLOGICAL EFFECTS

200 pm – 220 pm **Greg Ruggerone,** *Independent Scientific Advisory Board*
Density Dependence and Its Implications for Hatchery Supplementation and Habitat Restoration Programs in the Columbia River Basin

220 pm – 240 pm **Todd N. Pearsons,** *Grant County Public Utility District*
The Influence of Density-Dependence and Artificial Propagation on Natural Productivity of Spring Chinook Salmon in the Wenatchee Watershed

240 pm – 300 pm **Casey Ruff,** *Skagit River System Cooperative*
Using Bayesian State-Space Models to Evaluate the Effects of Density Dependence, Hatchery Conspecifics, and Environmental Conditions on the Productivity of Threatened Skagit River Steelhead

300 pm – 320 pm **Tuesday Afternoon Break**

320 pm – 340 pm **Koh Hasegawa,** *Hokkaido National Fisheries Research Institute*
Interspecific Interaction Between Wild and Hatchery Salmonid Fry

340pm – 400 pm **Teppo Vehanen,** *Natural Resources Institute Finland*
Wild and Hatchery Brown Trout Salmo Trutta Interact to Influence Feeding, Growth and Terrestrial Predation of Juveniles

400 pm – 420 pm **Ian Courter,** *Mount Hood Environmental*
Retrospective Analysis of a Natural-Origin Steelhead Population's Response to Exclusion of Hatchery Fish

420 pm – 440 pm **Maureen Kavanagh,** *Bonneville Power Administration*
Abundance and Relative Survival of Wild, ESA Listed Juvenile Winter Steelhead in a Tributary to the Lower Clackamas River, Oregon

440 pm – 500 pm **Anna Hagelin,** *Karlstad University*
Spawning Migration of Wild and Supplementary Stocked Landlocked Atlantic Salmon (*Salmo salar*)

500 pm – 520 pm **Eva Bergman,** *Karlstad University*
Downstream Migration of Atlantic Salmon – Possibilities for Wild Smolts and Quality of Reared Smolts

WEDNESDAY, AUGUST 19, 2015 (OREGON CONVENTION CENTER RM C-124)

PART 3A – HATCHERY PRACTICE OUTCOMES

800 am – 820 am **Daniel L. Bottom,** *NOAA Fisheries*
Hatchery Influence on Stock Composition, Habitat Use, and Life History Expression By Juvenile Chinook Salmon *Oncorhynchus tshawytscha* in the Columbia River Estuary

820 am – 840 am **Eric Knudsen,** *Prince Sound Science Center*
Field Studies of the Interactions of Wild and Hatchery Pink and Chum Salmon in Prince William Sound and Southeast Alaska

840 am – 900 am **Christopher P. Tatara,** *NOAA Fisheries*
Evaluating a Two-Year Smolt Rearing Program for Steelhead As a Hatchery Reform Tool to Enable Transition to Use of Locally-Derived Natural Broodstock

900 am – 920 am **Charles S. Erdman,** *University of Idaho*
Steelhead "Recycling" to Improve Angler Opportunity: How Can We Alter These Programs to Maximize Harvest and Minimize Impacts to Native Populations?

920 am – 940 am **Philip Simpson,** *Oregon Department of Fish and Wildlife*
Should I Stay or Should I Go Now? The Clash Between Residual Hatchery and Wild Steelhead in the Hood River, Oregon

PART 3B – PHYSIOLOGY

940 am – 1000 am **Brian Beckman,** *NOAA Fisheries*
Variations in Size, Growth and Survival of Hatchery and Wild Columbia River Chinook Salmon in the Northern California Current

1000 am – 1020 am **Wednesday Morning Break**

1020 am – 1040 am **Andrew Dittman,** *NOAA Fisheries*
Effects of Hatchery-Rearing Practices on Olfactory Imprinting and Homing in Pacific Salmon

1040 am – 1100 am **Donald Larsen,** *NOAA Fisheries*
Minijacks: Should These Small Fish be a BIG Concern for Chinook Salmon Supplementation Programs?

1100 am – 1120 am **Reiichiro Nakamichi,** *Tokyo University of Marine Science and Technology*
The Core Gene Expression Cascade during the Early Developmental Process Identifies Genetic Mechanisms for Salmonids Captive Breeding

PART 3C – PATHOGENS

1120 am – 1140 am **Maureen Purcell,** *U.S. Geological Survey*
Managing Infectious Disease Risks in Salmon and Steelhead Hatcheries and Natural Populations

1140 am – 1200 pm **Ian Bricknell,** *University of Maine*
The Ecology of Sea Lice in Cobscook Bay: Understanding the Interactions Between Wild and Farmed Hosts

1200 pm – 120 pm **Wednesday Lunch Break**

WEDNESDAY, AUGUST 19, 2015 (OREGON CONVENTION CENTER RM C-124)

PART 3D – POPULATION DYNAMICS AND MODELING

120 pm – 140 pm **Mark D. Scheuerell,** *NOAA Fisheries*
Analyzing Large-Scale Conservation Interventions with Bayesian Hierarchical Models: A Case Study of Supplementing Threatened Pacific Salmon

140 pm – 200 pm **Thomas Cooney,** *NOAA Fisheries*
Using Stochastic Life Cycle Models to Evaluate the Potential Response of Chinook Salmon Populations to Recovery Actions That Include Hatchery Supplementation

200 pm – 220 pm **David Venditti,** *Idaho Department of Fish and Game*
Effects of Salmon Supplementation in Idaho: 20 Years Later, What Do We Really Know?

220 pm – 240 pm **Kevin Goodson,** *Oregon Department of Fish and Wildlife*
Domestication Selection and Its Implications for Supplementation of Novel Species in the Pacific Northwest

240 pm – 300 pm **Wednesday Afternoon Break**

300 pm – 320 pm **Panel Discussion**

320pm – 340 pm **Panel Discussion**

AMERICAN FISHERIES SOCIETY
PORTLAND OREGON
145TH ANNUAL MEETING
AUGUST 16-20, 2015

INTERACTIONS BETWEEN HATCHERY AND WILD SALMONIDS
INTERNATIONAL UNDERSTANDING OF THE RISKS, BENEFITS, AND OPTIONS FOR MANAGEMENT

PRESENTATION ABSTRACTS

Part 1A - Hatchery Reform – Science and Perspectives

Hatchery Reform: What Have We Learned and Not Learned Since 1995?

Don Campton; *U.S. Fish and Wildlife Service*

Biologists first raised concerns in the 1970's regarding the effects of hatcheries on wild populations of Pacific salmon. These concerns peaked in the 1990's. Many of us questioned whether the perceived negative effects were (a) caused by inherent biological differences between "hatchery" and "wild" fish or (b) largely reflected management practices. In the past 20 years, we have learned that management practices (e.g., release location) can indeed affect fitness differences between hatchery and wild fish. We have also learned that "domestication selection" is real but that conflict between conservation and harvest goals creates additional risks. We have concluded – from our scientific reviews of hatcheries - that management goals for hatchery and wild fish need to be focused biologically at the population level with the goal of maximizing population viabilities regardless of the purpose of those fish (harvest, conservation, or both) or where those populations are intended to spawn (only in nature, only in a hatchery, or in both environments with a prescribed amount of gene flow between them). What we don't know is the extent to which these reforms can be implemented in face of existing practices, the biological attributes of the fish themselves, and logistic impediments to change.

A Broad-Scale View of Regional Hatchery Program Reform in Its Early Stages

Charles Huntington; *Clearwater BioStudies, Inc.*

The artificial propagation of Pacific salmon has become a cornerstone of fisheries management across much of the geographic range of these fish. Hatchery-based programs provide fish for harvest and can be managed to provide demographic support for populations at severe risk of extirpation. The programs are popular with many of the constituencies served by our fish management agencies, and provide employment for many in our profession. However, they are not without risk. Their effects (both ecological and genetic) on wild Pacific salmon are one of multiple reasons that many populations in the Pacific Northwest and California have been listed under the U.S. Endangered Species Act.

I examined the geographic scope and scale of hatchery salmon production along the eastern Pacific Rim, and then focused on programs operating in watersheds south of the Canadian border. Spatial data on the intensities of annual hatchery releases (fish numbers per unit area) were used to explore the degree of alignment between hatchery programs and watershed or landscape-based conservation priorities. The results raise questions about our strategies for managing hatchery programs consistent with the needs of wild Pacific salmon in the southern portion of their range, particularly during an era of climate change.

An Overview of Risks, Benefits and Best Management Practices in Pacific Northwest Salmon and Steelhead Hatchery Programs

Kathryn Kostow; *Oregon Department of Fish and Wildlife*

State and federal agencies in the Pacific Northwest, USA, annually release millions of hatchery salmon and steelhead into public waters. These hatchery programs are intended to provide fishery and conservation benefits but can pose risks to wild fish populations. Intended benefits include commercial, recreational and tribal fisheries in the ocean and regional rivers. Conservation benefits include reintroductions where historic populations are extinct and "safety-net" programs that maintain imperiled populations. However, some supposed benefits, particularly where hatchery fish "supplement" wild populations, remain controversial. Hatchery programs pose risks to wild fish when interbreeding decreases population fitness, or when the presence of hatchery fish, or hatchery facilities, affects how wild fish interact with their environment or with other species. Factors that particularly influence risk are the relative abundance and the relative genetic and life history similarity of hatchery and wild fish. Agencies and tribes in the Pacific Northwest are exploring management strategies that lower the risks and optimize the benefits of hatchery programs. This presentation will explore some of the factors contributing to risks, and review some of the strategies and guiding principles used in the Pacific Northwest for reducing risks and optimizing benefits.

A UK Perspective on Atlantic Salmon Stocking Illustrated by the River Tyne Stocking Programme

Nigel Milner[1], Ian Russell[2], Miran Aprahamian[3], Roger Inverarity[3], Jon Shelley[3], and Phil Rippon[3]

[1]APEM Ltd, Bangor University; [2]Cefas; [3]Environment Agency

The River Tyne, North East England, currently supports the largest catches of Atlantic salmon (*Salmo salar* L.) in England and Wales. The primacy of the Tyne developed from a state in the 1950s when no rod-caught fish were reported, because of serious long term industrial and urban pollution in the estuary (low dissolved oxygen and high ammonia). The recovery of the river began in the late 1960s through combined effects of industrial decline and active pollution control, which accelerated through the late 1970s. In the 1980s, a large stocking scheme began to mitigate for the new Kielder reservoir built on the upper North Tyne. Coincidence of the stock recovery and the stocking has led to conflicting claims for the role of stocking *vs* environmental improvements. A detailed quantitative review of the stocking programme has now shown that both were involved, but that water quality improvement played the major part. Stocking is estimated to have contributed 20% (range 9-43%) of the total cumulative spawning escapement up to the end of 1986 when its relative role was highest. Stocking continues for mitigation and stock restoration, but against a rapidly changing national perspective of the risks and benefits of stocking, which is outlined.

Part 1B – Management and Policy

Hatchery Programs of Chum Salmon in Hokkaido, Japan: Current Perspectives and Issues

Yasuyuki Miyakoshi and Mitsuhiro Nagata; *Hokkaido Research Organization*

In Japan, chum salmon *Oncorhynchus keta* stocks are managed by hatchery programs that constitute one of the largest hatchery programs in the world. The programs are successful for the purpose of increasing commercial catches in Hokkaido, northern Japan, and are currently conducted by non-profit salmon enhancement program associations. At present, there is no evidence of any decrease of genetic diversity in chum salmon in Japan despite the intensive hatchery programs. However, there are several other problems; e.g., a distinct difference in return rates has emerged among regions, early-runs have been increased but late-runs have decreased, and transplants of eggs and juveniles are

conducted. Hatchery programs should be the main management tool for chum salmon in the future because commercial fisheries cannot be sustained without hatchery programs in the narrow land area of Japan. It is hoped that researches on naturally spawning chum salmon will be advanced and novel management policies will be considered to restore naturally spawning salmon populations. After understanding the specific situations of fisheries management in Japan, scientific consideration of future management of chum salmon should be advanced, diffused and agreed by fishermen and hatchery managers.

Population Viability Improvements Following the Removal of a Hatchery Program in Salmon River (Oregon)

Kim K. Jones[1], Trevan J. Cornwell[2], Daniel L. Bottom[3], and Staci Stein[2]

[1]Oregon Department of Fish and Wildlife (retired); [2]Oregon Department of Fish and Wildlife; [3]NOAA Fisheries-National Marine Fisheries Service

Fisheries agencies have relied on hatchery production to meet harvest and supplementation objectives for 150 years, and once in place, such programs usually have become institutionalized. A number of recent genetic studies and meta- and retrospective analyses have documented reduced productivity of wild salmon and steelhead that interbreed with hatchery-reared fish, raising concerns about the long-term viability and recovery of at-risk stocks. In 2007 the Oregon Department of Fish and Wildlife discontinued a coho salmon hatchery program at Salmon River to support recovery of a "threatened" wild coho population in the Oregon Coast ESU. This decision constituted a unique management "experiment" allowing direct measurement of the wild population response following the discontinuation of a decades-old hatchery program. We quantified the response of two generations of coho salmon from the 2006 through 2011 brood years; spawner to recruit ratios shifted from a fraction of, to equal that in neighboring populations, spawn timing moved closer to historic timing, and survival rates and life history diversity increased. Our results documented a rapid improvement in multiple population viability metrics within two generations, indicating that discontinuing a hatchery program can be an effective management action to meet conservation and harvest goals.

Introspection and Innovation: AFS and Hatcheries and Management of Aquatic Resources

Jesse T. Trushenski; *Southern Illinois University Carbondale*

"A good price for and promotion of their products [cultured fish] were of paramount concern in the early years [of AFS]."

"With the passage of time, […] the focus of fisheries management broadened from the previous narrow fixation on fish culture to more appropriate, ecologically oriented programs."

"The arc of the fish culture pendulum has come full swing: from early consideration as a universal fisheries management panacea through a transitional period of questioning and disrepute, to final recognition as an indispensable tool..."

These quotes from Fish Culture in Fisheries Management (Stroud 1986) illustrate the changing role of cultured fish in aquatic resource management, as well as the Society's changing views on fish culture, from our founding in 1870 as the American Fish Culturists' Association to the present day. This evolution is the result of decades-long introspection and analysis, punctuated by forums coordinated by AFS to collectively discuss the use of hatchery-origin fish.

This presentation will summarize the iterative process AFS has undergone to evaluate and prepare recommendations regarding hatchery operation and the use of hatchery-origin fish, concluding with a synopsis of the guidance resulting from the most recent forum, "Hatcheries and Management of Aquatic Resources (HaMAR)".

A Synthesis of Findings from an Integrated Hatchery Program after Three Generations of Spawning in the Natural Environment

David Fast[1], Curt Knudsen[2], **William Bosch[1]**, Gabriel Temple[3], Anthony Fritts[3], Mark Johnston[1], Todd N. Pearsons[4], Donald Larsen[5], Andrew Dittman[5], Charles Strom[1], and Darran May[6]

[1]Yakama Nation; [2]Oncorh Consulting; [3]WDFW; [4]Grant County Public Utility District; [5]NOAA Fisheries-Northwest Fisheries Science Center; [6]University of Washington

The Cle Elum Supplementation and Research Facility in the Yakima River Basin, Washington is an integrated spring Chinook Salmon *Oncorhynchus tshawytscha* hatchery program designed to test whether artificial propagation can increase natural production and harvest opportunities while keeping ecological and genetic impacts within acceptable limits. An unsupplemented population in the adjacent Naches watershed provides a reference for evaluating environmental influences. The program has been comprehensively monitored from inception. A synthesis of findings includes: supplementation increased harvest, redd counts, and spatial distribution of spawners; natural-origin returns were maintained; straying to non-target systems was negligible; natural-origin females had slightly higher breeding success (production of surviving fry) in an artificial spawning channel, while behavior and breeding success of natural- and hatchery-origin males were similar; hatchery-origin fish showed differences in morphometric and life history traits; high rates of hatchery age-2 (mini-jack) production were reported but observed proportions of outmigrating juvenile and adult (ages 4 and 5) returning males were comparable for hatchery- and natural-origin fish; hatchery smolts did not affect levels of pathogens in natural smolts; and, ecological interactions attributed to the program were within adopted guidelines. Continued study is required to assess long-term impacts to natural production and productivity.

Conservation and Consumption: Nez Perce Tribe Duty and Obligation

Jason Vogel, Jay Hesse, and Ryan N. Kinzer; *Nez Perce Tribe*

As salmon populations continued to decline, hatcheries that were constructed to mitigate for impacts of human development (dam construction and habitat destruction) and provide fish for harvest have evolved to meet both conservation and consumption objectives. Tribes, in conjunction with co-managers, have implementing sliding scales that balance hatchery and harvest actions relative to adult return sizes. Under these sliding scales, hatchery fish contribution to natural production is increased at low natural returns levels and decreased as natural run size increases. Likewise, harvest rates (including natural retention) are adjusted relative to natural run size. With the reality of continued human impacts to "natural" ecosystems and ongoing hatchery production to mitigate those impacts, is it possible to move beyond the conservation and consumption balance toward recovery? We believe the restoration of natural-origin Snake River fall Chinook to a 10 year geometric mean abundance of over 8,000 demonstrates that there is hope. The Tribe's expectations remain fixed on achieving generationally sustainable broad sense recovery, in a manner that achieves conservation and consumption. However, the existence of divergent expectations and legal mandates begs the question "how good is good enough"? The answer relies on input from science, policy, and legal perspectives.

Oregon's Coastal Plan: A Walk on the Wild (and Hatchery) Side

Ed Bowles; *Oregon Department of Fish and Wildlife*

Oregon's coastal watersheds include numerous healthy wild salmon and steelhead populations, many of which support robust fisheries. This is somewhat unique in the contiguous United States. Oregon also maintains hatchery programs that augment coastal fisheries. These wild and hatchery fisheries are vital to coastal economies and culture. Oregon's Native Fish Conservation Policy requires maintaining a platform of conservation sustaining wild native species, upon which hatchery and wild fisheries are provided consistent with conservation. This policy is being implemented for much of

Oregon's coast through the Coastal Multi-Species Conservation and Management Plan (Coastal Plan), developed through a comprehensive science and stakeholder process. The Coastal Plan assessed the status of wild populations; developed strategies to shift at-risk populations to viable status and further enhance existing viable populations; established a portfolio of wild and hatchery fish emphasis areas; and solidified research, monitoring and evaluation programs for adaptive management. Successful implementation of the Coastal Plan will ensure conservation of wild fish species and their habitats and provide a robust and diverse blend of wild and hatchery supported fisheries. Oregon believes this management approach allows for responsible conservation of wild populations while also providing successful fisheries based on both wild and hatchery fish.

Session 2A – Genetic Effects

Genetic Interactions between Hatchery and Wild Fish: Japanese Chum Salmon Perspectives

Shuichi Kitada[1], Reiichiro Nakamichi[1], and Hirohisa Kishino[2]

[1]Tokyo University of Marine Science and Technology; [2]The University of Tokyo

The Japanese chum salmon hatchery program successfully increased fishery production since 1970s with average return rates of 3.7±1.2% in Hokkaido and 1.7±0.6% in Honshu. In the recent decades, return rates consistently decreased with large variations, and the decreasing trend is steeper in Honshu. However, little is known about genetic effects of Japanese chum salmon hatchery practices. Here, we review literature on this subject, and describe an overview on interactions between hatchery and wild chum salmon. Intensive Japanese chum salmon supplementation for early run populations altered the distribution of run timing of chum salmon in Hokkaido, but the genetic diversity remains high compared with other populations in the Pacific Rim. Empirical Bayes microsatellite F_{ST} described a fine scale population structure consisted of seven regional groups (five in Hokkaido, two in Honshu), generally agreeing with previous studies, but some populations were nested which might reflect translocation history of hatchery fish. The mitochondrial DNA control region F_{ST} was approximately six times larger than that for the microsatellite loci, and resulted in a stepping stone structure with persistent translocation effects, suggesting more conservative female toward spawning grounds (smaller straying).We will discuss on fitness of hatchery fish and future challenges for Japanese chum salmon hatcheries.

Supplementation with Local, Natural-Origin Broodstock May Minimize Negative Fitness Impacts in the Wild

Maureen A. Hess[1], Craig Rabe[2], Jason Vogel[2], Doug Nelson[2], Shawn R. Narum[1]

[1]Columbia River Inter-Tribal Fish Commission, Hagerman Genetics Lab; [2]Nez Perce Tribe

We investigate relative reproductive success (RRS) of an ongoing supplementation program for Chinook salmon in Johnson Creek, Idaho. Pedigrees of natural and hatchery-origin fish from five broodyears were tracked over two generations with molecular markers. Results show that hatchery-reared females had no detectable difference in fitness relative to natural-origin females (overall RRS=1.03, p=0.55), but hatchery-reared males had lower fitness than their natural-origin counterparts (overall RRS=0.84, p=0.04; jack male RRS=0.91, p=0.05). Since individuals that do not produce returning adult offspring have no direct genetic effect on the population, we also compared RS between the hatchery and natural-origin fish that contributed at least one offspring to the next generation and found that RS was not significantly different for either sex (female RRS=1.05, p=0.99; male RRS=0.96, p=0.79; jack male RRS=1.24, p=0.35). Additionally, RRS of hatchery-reared fish (H) that mated with natural-origin fish (HxN matings) were equivalent (RRS=1.00, p=0.71) to those between two natural fish (NxN), with HxH matings having lower overall RRS of 0.85 that was not statistically significant (p=0.43). Results suggest that supplementation with 100% local, natural-origin broodstock may be a practice that can successfully boost population size with minimal negative genetic impacts to wild populations.

Linking Genotype and Phenotype: Identifying Fitness Traits That Respond to Genetic Adaptation to Captivity in Chinook Salmon

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The success of conservation hatcheries may be limited if hatchery fish have reduced reproductive success in the wild. Genetic adaptation to captivity has been identified as one mechanism of this fitness reduction. Therefore, it is important to identify the specific traits that respond to selection in the captive environment and quantify the rate of genetic change, because this data can inform actions that maximize the effectiveness and longevity of hatchery programs. Previous work on hatchery Chinook salmon from the Cle Elum Supplementation and Research Facility surveyed 9410 restriction site-associated loci and identified genomic signatures in a segregated line that are consistent with adaptation to captivity. Here, we link key fitness traits that have been measured in five generations of returning adults to molecular markers using Genome Wide Association Studies and Random Forest analyses. We then perform tests of selection on associated markers to determine which traits respond to genetic adaptation to captivity. We compare our results to an integrated line to determine whether gene flow between hatchery and naturally spawned fish limits directional change at fitness loci. This study will inform management practices aimed at reducing selection in the captive environment, thus minimizing its effect in supportive breeding programs.

Abernathy Creek Steelhead: Population Genetics and Reproductive Success at a Conservation Hatchery with Wild Broodstock Integration

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Integrated hatchery programs typically strive to prevent genetic divergence between hatchery-origin (HOR) and natural-origin (NOR) components of the population. The goal of this project was to determine the natural reproductive success and mean relative fitness of HOR and NOR steelhead (*Oncorhynchus mykiss*) in Abernathy Creek, WA. The Abernathy Fish Technology Center (AFTC) developed an integrated steelhead broodstock in 1999 starting with pre-smolt NOR juveniles collected from throughout Abernathy Creek and then rearing the broodstock to maturity in the hatchery. From 2003 thru the present, NOR juveniles have been captured and compared with samples collected from the progeny of AFTC's broodstock to assess genetic changes associated with captive rearing of steelhead. With the return of the first adults produced from the original 1999 broodstock, AFTC has had a policy of maintaining ~25% NOR integration in the broodstock, with the remaining returning NOR steelhead being released back into the stream to reproduce naturally. In addition, from 2005 thru the present, both returning adult HOR and NOR steelhead have been captured and genetic samples taken. The resulting dataset has allowed us to assess the relative reproductive success and genetic characteristics of the annual broodstock compared to fish produced in the stream.

Natural Production and Genetic Introgression from Hatchery Summer Steelhead in the Upper Willamette River

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Since 1966, the Oregon Department of Fish and Wildlife has managed a summer Steelhead *Oncorhynchus mykiss* hatchery program in the upper Willamette River (UWR) to mitigate for impacts of Willamette Valley Project dams. Summer Steelhead are not native to the UWR, and may pose genetic and ecological risks to native, ESA-listed winter Steelhead. To evaluate natural production by and introgression from summer Steelhead, we collected tissue samples from unmarked smolts at Willamette Falls in 2009-2011. We then used microsatellite data to assign these individuals as summer Steelhead, winter Steelhead, resident Rainbow Trout or hybrids. We found that about 10% of sampled fish were naturally-produced summer Steelhead and an additional 10% were hybrids with >20% summer Steelhead ancestry. To investigate spatial patterns of natural production by summer Steelhead, we electrofished 196 randomly selected UWR sites in summer 2014. We collected 464 juvenile *O. mykiss* samples from 65 of these sites. These samples, baseline samples, and those collected in 2009-2011 were genotyped at a suite of single nucleotide polymorphisms, identified through restriction site-associated DNA sequencing and alignment. We analyzed these data to map summer steelhead natural production, refine previous hybridization estimates, and assess implications for the recovery of UWR winter steelhead.

Genomic Signatures of Domestication in Two Independently Developed Hatchery Steelhead (*Oncorhynchus mykiss*) Strains Propagated in Western Washington

Sewall F. Young and Kenneth I. Warheit; *Washington Department of Fish and Wildlife*

Two hatchery strains of steelhead, a summer run and a winter run strain, were developed in the 1940s and 1950s to provide fish for harvest in recreational fisheries. Founders for both strains were selected from early maturing fish. Progeny were reared for a single year before release – natural populations in the region typically spend two years rearing in freshwater – and subsequent generations of broodstock were drawn from returning adults, effectively selecting parents that completed their life-cycle with a single winter of feeding and care in hatcheries. We used restriction-site associated DNA (RAD) sequencing to discover over 20,000 polymorphic loci in 10 haploid steelhead families that represent 3 domesticated and 2 non-domesticated breeding groups. We constructed dense linkage maps and selected a set of broadly-distributed loci to use in scanning for patterns of polymorphism that differentiate domesticated and naturally-produced populations.

Domestication Selection and Loss of Fitness in Hatchery Salmon and Steelhead: Possible Mechanisms for Fitness Loss

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It is well established that hatchery-origin Atlantic and Pacific salmon often have lower fitness (reproductive success) in the wild than natural-origin fish. Data from six studies on four species of salmon and steelhead show that this phenomenon is general and occurs when hatchery fish are produced from local and predominantly wild broodstock. Furthermore, there is evidence in steelhead that the fitness decline is a heritable effect resulting from rapid genetic adaptation to captivity (domestication). What traits are under selection in hatcheries, and what aspects of hatchery culture exacerbate the rate

of domestication? Answers to those questions might identify ways in which hatchery practice could be modified to slow domestication. Circumstantial evidence from Hood River steelhead suggests that high rearing densities (crowding) increase the rate of domestication. If true, possible mechanisms include (1) that increased crowding increases the among-family variance in performance, and (2) that strong family-by-environment effects cause large changes in family rank-order performance across rearing densities. However, in 2 years of experiments on varying rearing density in hatchery culture of steelhead, we found no evidence to support either hypothesis. We therefore propose a new model of how high rearing density might exacerbate domestication in hatchery reared steelhead.

Ecological and Genetic Effects of a Conservation Hatchery on Natural-Origin Steelhead: Lessons from a Decade-Long Study in Abernathy Creek, Washington

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Hatcheries have long been used for supplementation of threatened and endangered Pacific salmon (*Oncorhynchus* spp.) in the Pacific Northwest, though traditional hatchery practices can pose ecological and genetic risks to local salmon populations. Our goal was to test whether proposed conservation hatchery techniques such as developing local broodstocks and maintaining integration between hatchery-origin (HOR) and natural-origin (NOR) populations could minimize negative ecological and genetic impacts of a hatchery program to a steelhead (*O. mykiss*) population. A local broodstock was obtained by rearing captured age 0+ NOR juveniles to sexual maturity, and the HOR population has been integrated with the NOR population since 2003. Hatchery supplementation has successfully increased the abundance of HOR steelhead in Abernathy Creek, while the results for adult and juvenile NOR steelhead abundance in the creek have been mixed. Morphological and physiological differences persist between HOR and NOR steelhead at various life history stages. The HOR population showed genetic divergence from the NOR population, a reduction in the effective number of breeders, and an increase in temporal population structure. These differences suggest that the implementation of these conservation hatchery techniques has not been sufficient to alleviate the ecological and genetic risks associated with supplementation in this population.

Understanding the Colonization History of Chinook Salmon in Patagonia Using Single Nucleotide Polymorphisms (SNPs): Gauging the Effects of Artificial Vs. Natural Propagation

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Chinook salmon (*Oncorhynchus tshawytscha*) in South America have rapidly colonized Patagonian Rivers, likely mediated by both introductions (1970–1991) followed by dispersion from either farmed broodstock or already naturalized populations in more recent years (1991–Present). We genotyped 270 Chinook salmon sampled between 2003 and 2013 from six Pacific and two Atlantic basins through a panel of 190 SNPs developed from the native range in North America. Using population- and individual-based inference, our goals were three-fold: (1) quantify the contribution of donor (native) populations to introduced populations, (2) identify the number of gene pools among introduced populations using Bayesian inference, and (3) test for signals of reduced diversity among Atlantic populations, which were presumably founded from a reduced number of immigrants of Pacific origin. We found (1) variable contributions of donor populations among basins, consistent with early stocking practices and more recent imports for farming; (2) three distinct genetic

pools: two in the Pacific and one in the Atlantic; (3) and lower genetic diversity among Atlantic basins than Pacific basins, suggesting a founder effect from Chinook salmon strays from the Pacific. A combination of both artificial and natural propagation might explain the rapid colonization of Chinook salmon in South America.

Maintenance of Genetic Diversity During Reintroduction: Assessment Among Potential Parents, Offspring, and Migrants at Two Spring Chinook Salmon Programs

Nick Sard, Melissa Evans, Dave Jacobson, Kathleen G. O'Malley, and Michael Banks; *Oregon State University*

Reintroduction programs provide salmonid populations access to historical habitat, however little is known about the demographic and evolutionary consequences of these actions. Here we evaluated if genetic diversity was maintained in two reintroduction programs, because maintenance of genetic variation is important for maximizing future adaptive potential. Using previously constructed genetic pedigrees and associated microsatellite genotypes, we examined whether genetic diversity was maintained between reintroduced cohorts and F_1 progeny (age-3 to age-5) that returned in subsequent years to dams on the South Fork McKenzie and South Santiam rivers, Oregon. In all comparisons, the average number of alleles observed at each locus decreased between potential parents and offspring; however observed heterozygosity did not differ. Results suggest that most alleles were lost as a result of genetic drift, likely mediated by the highly skewed fitness of reintroduced salmon/parents. However our results also indicated that migrants, defined here as individuals not produced above dams, restored some genetic variation that was lost between potential parents and offspring, and contributed genetic variants not previously observed in reintroduced salmon. Our results indicate that gene flow will be vital to the long term viability of these reintroduction programs.

Spawning Interactions Between Hatchery and Wild Steelhead and Spring Chinook Salmon in the Klickitat River, Washington: Results from Radio Telemetry and Genetic Investigations

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Steelhead and spring Chinook salmon populations in the Klickitat River in south central Washington consist of both hatchery and wild fish. Genetic monitoring indicates that hatchery and wild steelhead in the Klickitat remain distinct, suggesting low introgression rates. Radio telemetry observations indicate spatial and temporal separation in spawning adult steelhead. Of natural-origin steelhead that spawned in the wild, 64% spawned in the middle or upper mainstem Klickitat or in tributaries to this river reach, while 90% of hatchery steelhead spawned in the lower mainstem Klickitat or in tributaries to this reach. Hatchery steelhead also exhibited a lower rate of spawning behavior in the wild. For hatchery steelhead, observed spawning started in November, with 75% of the spawning ending by mid-March. For wild steelhead, 85% of spawning started after mid-March and spawning ended in May. In spring Chinook, genetic analysis indicates a high degree of interbreeding, and spatial and temporal overlap was observed in hatchery- and natural-origin spawners. Different hatchery program characteristics and broodstock sources between these species are likely driving these contrasting results; reforms are planned with continued monitoring for both programs. Monitoring of individual populations and programs is key to informed hatchery evaluations and management decisions.

Session 2B – Genetic and Ecological Effects

Adaptive Management and the Nez Perce Tribal Hatchery Spring Chinook Salmon Supplementation Program

Justin Bretz; *Nez Perce Tribe*

Beginning in 2003, the Nez Perce Tribe implemented a supplementation program in the Clearwater River basin with the goal of restoring spring Chinook salmon populations to self-sustaining levels and provide harvest opportunities for Tribal and non-Tribal anglers. This program utilizes fall releases of pre-smolt life stages, low density rearing and acclimation to best mimic natural production and minimize ecological impacts. Hatchery and natural juveniles and adults were evaluated using abundance, survival and productivity performance measures. Although overwinter survival of hatchery origin presmolts was low, surviving smolts demonstrated similar survival to Lower Granite Dam (LGR) and similar smolt-to-adult survival from LGR to LGR compared to natural origin smolts. Finally, adult age structure (including jack proportions) of returning hatchery origin adults was similar to that of natural production. Overall, the results suggest that a pre-smolt release strategy may minimize impacts by producing fish similar to that of the natural population. However, survival from release to the smolt stage was very low and resulted in hatchery abundance levels well below the goals of the program. An adaptive management framework was developed to evaluate alternative hatchery management approaches that can meet the program goals and limit impacts to natural populations.

The Good, the Bad and the Ugly: California Chinook Salmon and Steelhead Hatcheries and Their Apparent Influence on Wild Stocks

Brad Cavallo; *Cramer Fish Sciences*

California anadromous salmonids exist at the southern extent of the species range, and over the last half-century have lost access to the majority of historic spawning habitat. Fall-run Chinook and steelhead hatchery programs were initiated to mitigate for lost habitat, but recently available data suggest hatcheries may be a substantial threat to conservation and recovery of wild stocks. In 2006, a constant fractional marking (CFM) program was implemented among fall Chinook hatchery programs. Results now available show the proportion of hatchery fish on the spawning grounds (pHOS) and in use as hatchery broodstock (pHOB) in many systems far exceeds what is considered damaging to genetic characteristics and fitness of natural origin stocks. Steelhead produced in most California hatcheries have been 100% marked since 1998, greatly simplifying estimation of natural origin composition. Similar to fall Chinook, available information suggests wild origin steelhead are being replaced, not just supplemented, by hatchery production. Studies to address the fitness, life history diversity and population viability consequences of hatchery dominance have begun only recently, but findings to date suggest losses in adaptive traits critical to success in California's unforgiving freshwater, estuarine and marine environments.

Session 2C – Ecological Effects

Density Dependence and Its Implications for Hatchery Supplementation and Habitat Restoration Programs in the Columbia River Basin

Greg Ruggerone; *Independent Scientific Advisory Board*

This presentation highlights key findings regarding hatchery supplementation, habitat restoration and salmon recovery, based on the Independent Scientific Advisory Board's (ISAB) 2015 report on density dependence in the Columbia River Basin: (1) Historical estimates of average all-species abundance in the Columbia Basin are likely over-estimated, but they are still much greater than today. (2) Density dependent responses are common in the Columbia Basin and appear

sufficiently strong to constrain recovery of many ESA-listed populations, including those in pristine natal areas. (3) Hatchery spawners are intended to boost natural populations and may do so in some areas, but abundances on the spawning grounds often exceed current capacity, leading to unsustainable natural production and an inability to achieve an integrated hatchery approach—a key rebuilding strategy. (4) Hatchery spawners lower intrinsic productivity and also inhibit the natural rebound in productivity associated with lower density. (5) Culling surplus hatchery fish would increase population productivity, help achieve sustainability, and contribute to harvest goals. (6) The ISAB recommends balancing hatchery supplementation efforts with riverine capacity while implementing restoration actions that reduce limitations imposed by density dependence. The ISAB serves the Northwest Power and Conservation Council, NOAA Fisheries, and Columbia River Indian Tribes.

The Influence of Density-Dependence and Artificial Propagation on Natural Productivity of Spring Chinook Salmon in the Wenatchee Watershed

Todd N. Pearsons[1], Michael J. Ford[2], Tracy Hillman[3], Eric R. Buhle[2], Andrew Murdoch[4], Peter J. Graf[1], and Catherine Willard[5]

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Density-dependence and artificial propagation have repeatedly been shown to influence natural productivity of salmon; however, the relative influence of these factors has rarely been compared to determine how they reduce productivity across a range of spawner abundances. Comparisons can be challenging because of a correlation between hatchery-origin spawner abundance and total spawner abundance. Density-independent survival of stream-type Chinook salmon in the Wenatchee River Basin was modelled and compared to density-dependent and hatchery-origin influenced fish survival across a range of spawner abundances. Other methods were also explored to estimate mortality influenced by density and artificial propagation and to tease out confounding factors. Evidence for both density-dependent and hatchery-origin caused mortality was detected. The proportion of total mortality attributed to density-independence, density-dependence, and artificial propagation was estimated and compared to spawner abundance. Differences in the proportion of mortality caused by various factors at increasing spawner abundance can help explain conflicting results from published studies. Furthermore, results can have important implications for whether habitat actions, artificial propagation, or both should be employed to achieve management objectives.

Using Bayesian State-Space Models to Evaluate the Effects of Density Dependence, Hatchery Conspecifics, and Environmental Conditions on the Productivity of Threatened Skagit River Steelhead

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Successful recovery of threatened populations of Puget Sound steelhead (*Oncorhynchus mykiss*) will undoubtedly require knowledge of the predominant processes affecting population productivity. Here we fit a hierarchical Bayesian spawner recruit model to a 33 year data set of escapement, catch, and age composition estimates from a terminal fishery for adult wild steelhead in the Skagit River basin to examine the effect of density dependence and other life-stage specific covariates on population dynamics. Our analysis provides four important results regarding factors affecting productivity of wild Steelhead in the Skagit River basin: (1) productivity is strongly limited by the availability of habitat, presumably in freshwater, due to density dependent processes; (2) productivity is negatively correlated with releases of hatchery reared steelhead smolts; (3) productivity is negatively correlated with large peak winter flow during the first freshwater winter;

and (4) productivity is positively correlated with warm phases of the Pacific Decadal Oscillation (PDO) during the first year of ocean residency. The modeling framework employed in spawner recruit analyses not only allows for a better understanding of the point estimates of model parameters including intrinsic productivity, density dependence, and covariates, but also the uncertainty around them.

Interspecific Interaction Between Wild and Hatchery Salmonid Fry

Koh Hasegawa; *Hokkaido National Fisheries Research Institute*

Although multiple species of salmonids inhabit streams sympatrically under the effect of both intra- and interspecific interactions, primarily competition, previous studies mostly focused on intraspecific interactions and studies on interspecific interactions are very rare. I therefore studied the effects of hatchery chum salmon fry on wild chum and masu salmon fry by enclosure experiments and field survey. The enclosure experiments demonstrated that hatchery chum salmon decreased wild chum salmon foraging efficiency and growth. These results suggest that hatchery chum salmon decreased survival of wild chum salmon, and may influence seaward migration of wild chum salmon because high condition factor appeared to trigger migration onset. Conversely, masu salmon was not affected by hatchery or wild chum salmon. Instead, masu salmon showed an intensive reduction in growth rate with increasing conspecific density. In a natural stream, however, stomach fullness of wild masu salmon fry decreased after explosion of hatchery chum salmon fry by stocking. Given these results, an extreme amount of hatchery fry stocking may influence wild fry regardless of competitive dominant hierarchy. Therefore, stocking procedures which mitigate the impact of hatchery fry on wild fry should be advanced for the effective management of both hatchery and wild salmonids.

Wild and Hatchery Brown Trout Salmo Trutta Interact to Influence Feeding, Growth and Terrestrial Predation of Juveniles

Teppo Vehanen and Ari Huusko; *Natural Resources Institute Finland*

We studied the growth, prey consumption and vulnerability to predation of juvenile hatchery and wild brown trout of similar genetic origin. Two experiments were run: one in in 12 wire mesh cages in a natural stream, and the other one in three semi-natural flumes in North-Eastern Finland. A substitute design with three treatments was used in both experiments: both hatchery trout and wild trout in allopatry, and hatchery and wild trout in sympatry. Wild trout started feeding shortly after the start of the experiment, and clearly earlier than novel hatchery trout, but food consumption was negatively affected by the presence of hatchery trout. When accompanied with wild trout, novel hatchery trout started to feed earlier and consumed more live prey when than when in allopatry. Growth of wild brown trout was negatively affected by the presence of hatchery trout in cage experiment, but not in semi-natural flumes. Two American minks, *Neovison vison*, entered the area of semi-natural streams and preyed on juvenile brown trout in different treatments. Hatchery trout were consumed significantly more than wild trout. When in sympatry with hatchery trout more wild trout were eaten by minks compared to pure wild trout treatments.

Retrospective Analysis of a Natural-Origin Steelhead Population's Response to Exclusion of Hatchery Fish

Ian Courter[1] and Garth Wyatt[2]

[1]*Mount Hood Environmental;* [2]*Portland General Electric (PGE)*

We conducted a retrospective analysis with Upper Clackamas River steelhead population census data to determine the cause of a notable decline in natural-origin winter steelhead spawner abundance during adult return years 1972-1998. It was asserted that out-of-basin hatchery summer steelhead directly competed with native juvenile winter steelhead for

rearing habitat, thereby causing the decline in winter steelhead abundance. If this casual mechanism were accurate, a population increase would be expected to occur following hatchery fish exclusion (1999). However, we found that hatchery summer steelhead did not affect winter steelhead returns, and winter steelhead abundance in the Upper Clackamas River did not rebound to levels observed during the years preceding hatchery stocking. Instead, fluctuations in winter steelhead abundance were correlated with other regional winter steelhead stocks. There is strong covariation between productivity of contiguous steelhead populations, and this covariance declines with increasing distance between watersheds. Therefore, the decline in abundance of natural-origin steelhead in the Upper Clackamas River (1972-1998) was principally driven by survival rates common to steelhead populations in the Lower Columbia/ Willamette River region. Our analysis provides evidence that summer steelhead hatchery programs in the Clackamas Basin can coexist with natural-origin winter steelhead populations without impairing winter steelhead productivity.

Abundance and Relative Survival of Wild, ESA Listed Juvenile Winter Steelhead in a Tributary to the Lower Clackamas River, Oregon

Maureen Kavanagh, *Bonneville Power Administration*

It has been well documented that naturally spawning hatchery fish negatively impact population productivity and have lower adult survival than their wild counterparts (Araki et al. 2007; Chilcote 2003; Lynch and O'Hely 2001). Eagle Creek National Fish Hatchery spawns and rears juvenile coho salmon (*Oncorhynchus kisutch*) and juvenile steelhead trout (*Oncorhynchus mykiss*) that are released into Eagle Creek within the Clackamas River Basin, OR. The hatchery operates within the confines of the Endangered Species Act (ESA), however past investigations on the ecological and genetic impacts of hatchery steelhead in Eagle Creek indicated that in some years natural production was influenced by natural spawning of hatchery fish (Kavanagh et al. 2009). Using Passive Integrated Transponder (PIT) tag technology, we initiated a three year study (2010-2012) comparing relative survival and abundance of juvenile steelhead in Eagle Creek to that in North Fork Eagle Creek, the primary producer of wild winter steelhead in the lower Clackamas River Basin. Adult return data is being collected through 2015 and will be used to determine if freshwater productivity and survival in Eagle Creek is being impacted by naturally spawning hatchery fish.

Spawning Migration of Wild and Supplementary Stocked Landlocked Atlantic Salmon (*Salmo salar*)

Anna Hagelin, Olle Calles, Larry Greenberg, John Piccolo, and Eva Bergman; *Karlstad University*

Upstream migration by adult salmonids is hindered by dams in many regulated rivers. In the River Klarälven, which possesses a unique population of landlocked Atlantic salmon, *Salmo salar,*, the loss of fish production is compensated for by stocking hatchery-reared smolts and by collecting upstream migrating spawners in a trap at the lowermost dam and transporting them past 8 dams. To identify the spawning grounds and study their behavior, wild and hatchery-reared, radio-tagged Atlantic salmon were followed during their spawning migration. Approximately 50% of the hatchery-reared salmon “fell” downstream of the uppermost power plant and thus did not reproduce. For wild fish, early migrants fell downstream of the dam to a greater extent than late migrants (50% vs 10% fallbacks). The hatchery-reared salmon’s migration pattern was also more erratic and they held position on the spawning grounds less often and for shorter time than the wild salmon. Our results indicate that the capacity of hatchery-reared salmon as supplementary spawners is limited and hence their reproductive contribution to the wild population is smaller than previously believed.

Downstream Migration of Atlantic Salmon – Possibilities for Wild Smolts and Quality of Reared Smolts

Eva Bergman[1], Johnny Norrgård[1], John Piccolo[1], Monika Schmitz[2], and Larry Greenberg[1]

[1]Karlstad University; [2]Uppsala University

Populations of migratory salmon and trout have shown a decline worldwide due to human activities, and over the years, numerous measures have been undertaken to maintain these populations. The regulated River Klarälven-Lake Vänern ecosystem hosts endemic populations of landlocked Atlantic salmon (*Salmo salar*), but at much lower abundances than in the early 1800s. After the completion of the last of nine Swedish hydroelectric power stations in the 1960s, the Klarälven salmon population reached an all-time low, and an extensive stocking and transportation of spawners past the dams has resulted in a population increase. To obtain information needed to produce a management plan we conducted a series of studies of downstream-migrating smolts to estimate hydropower station passage success and to compare migratory success of wild and hatchery reared smolts. Only 16-30% of the wild smolts passed all eight power plants, and losses were generally lower for wild than hatchery smolts in the dam-free lower 25 km of the river. Moreover, the large differences in migration success of the hatchery smolts could be related to feeding routines in the hatchery. We conclude that production of high quality hatchery-raised smolts, together with remedial measures to increase the number of wild salmon, are needed.

Session 3A – Hatchery Practice Outcomes

Hatchery Influence on Stock Composition, Habitat Use, and Life History Expression by Juvenile Chinook Salmon *Oncorhynchus tshawytscha* in the Columbia River Estuary

Daniel L. Bottom, David J. Teel, Susan A. Hinton, and G. Curtis Roegner; *NOAA Fisheries*

The Columbia River is an example of a large basin where salmon populations are managed simultaneously for phenotypic simplicity (through hatchery production to mitigate for habitat loss) and phenotypic complexity (through habitat restoration to enhance life history expression and survival). We synthesized recent survey data to evaluate effects of this dual management approach on juvenile Chinook salmon in the estuary. The results indicate that the estuarine life histories of most Chinook are now driven by hatchery programs. Hatchery releases determine salmon abundance patterns, stock composition, and size distributions in the estuary. On average hatchery Chinook enter the estuary at larger sizes, seek deeper channel habitats further from shore, concentrate nearer the river mouth, and migrate faster than many smaller, naturally-produced juveniles. Nonetheless, releases from scores of upriver facilities create a protracted estuary migration of hatchery juveniles that overlaps with naturally-produced Chinook, even in shallow habitats. Recent comprehensive hatchery reforms designed to integrate or segregate hatchery and wild stocks in natal streams do not account for interactions in the estuary. Our survey results raise questions about the ecological responses to concentrated pulses of similarly-sized hatchery fish and the effectiveness of habitat restoration in an estuary dominated by large hatchery phenotypes.

Field Studies of the Interactions of Wild and Hatchery Pink and Chum Salmon in Prince William Sound and Southeast Alaska

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Innovative field studies underway for the ADF&G Alaska Hatchery Research Program will meet three objectives: 1) Estimate proportions of hatchery-origin Pink Salmon and Chum Salmon entering Prince William Sound (PWS); 2) Determine extent and annual variability in stream straying of hatchery Pink Salmon in PWS, and Chum Salmon in PWS and

Southeast Alaska (SEAK); and 3) Assess relative fitness (productivity) of hatchery strays and wild in natural spawning areas. A subsample of gillnetted salmon from PWS entrances is being examined for presence of otolith thermal marks to estimate hatchery-origin proportions. We also sample spawn-outs in 32 PWS and 32 SEAK natural spawning populations to determine the proportion of hatchery-origin salmon. We intensively sample otoliths and genetic tissues from spawn-outs in six PWS Pink Salmon and four SEAK Chum Salmon populations to obtain origin and pedigree data to determine the relative reproductive success of hatchery and natural-origin salmon, and their crosses. Data from the PWS ocean and stream sampling will also be used to estimate the total run size of natural and hatchery origin spawners in natural systems in PWS and SEAK. Preliminary results for 2013 PWS ocean hatchery proportions and PWS and SEAK stray rates will be discussed.

Evaluating a Two-Year Smolt Rearing Program for Steelhead As a Hatchery Reform Tool to Enable Transition to Use of Locally-Derived Natural Broodstock

Christopher P. Tatara[1], Matt Cooper[2], William Gale[2], Chris Pasley[2], Benjamen M. Kennedy[2], Penny Swanson[1], Donald Larsen[1], Jon T. Dickey[3], Mollie Middleton[3], and Barry Berejikian[1]

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The combination of natural broodstock spawn timing and cold water temperatures precludes production of yearling smolts for some steelhead supplementation programs. We compared the performance (survival, migration, maturation, and residualism) of yearling smolts (S1) from non-local broodstock, and two-year smolts (S2) from local broodstock released from the Winthrop National Fish Hatchery over five release years. The majority (75-97%) of S1 and S2 males were immature; however, in two release years there was a significantly higher proportion of S2 males that were either precocious parr, or initiating maturation for the following year. S2 apparent survival was greater or equal to S1 survival in all 5 years and related to body size. Outmigration travel times were faster for S2 steelhead in all years. Residualism was similar in both programs and related to average size at release. Fifteen years of hatchery records show S1 steelhead are smaller and more variable than S2 at release, suggesting an S1 program produces smaller smolts with lower survival, slower travel time, and higher residualism than an S2 program. The S2 program minimizes genetic risks of nonlocal broodstock and ecological risks associated with reduced S1 smolt performance characteristics.

Steelhead "Recycling" to Improve Angler Opportunity: How Can We Alter These Programs to Maximize Harvest and Minimize Impacts to Native Populations?

Charles S. Erdman, Christopher Caudill, George Naughton, Michael Jepson, Matt Knoff, and Mark Morasch; *University of Idaho*

Each year, hundreds of thousands of adult salmon *Oncorhynchus* spp. and steelhead *O. mykiss* return to hatcheries throughout the Pacific Northwest. As broodstock quotas are met, a surplus of hatchery fish often exists, and recycling—the capture, transport, and then release of adult hatchery fishes back downstream—is used to increase angler opportunity in some locations. Recycled fishes that avoid harvest can remain in river systems, a concern in the Willamette River Basin, Oregon where non-native summer steelhead are recycled in tributaries that also have ESA-listed native winter steelhead populations. From 2012-2014, we radio-tagged 444 recycled summer steelhead in two Willamette River sub-basins to estimate behavior, distribution and fate of recycled summer steelhead. Telemetry records indicated that approximately 50% of radio-tagged recycled fish released in the South Santiam and Middle Fork Willamette Rivers were last detected in these tributaries, 9% and 18%, respectively, were reported harvested by anglers, and 9-26% strayed from their respective release tributary. Our data will allow managers to make more informed decisions on how to maximize harvest of these recycled fish while at the same time minimizing the impacts to native winter steelhead in the Willamette River Basin.

Should I Stay or Should I Go Now? The Clash Between Residual Hatchery and Wild Steelhead in the Hood River, Oregon

Philip Simpson; *Oregon Department of Fish and Wildlife*

Impacts to wild fish related to residualism of hatchery origin smolts are highly variable and potentially negative. Using existing PIT-tag data, our objectives for this study were to 1) quantify the potential minimum level of residualism and 2) assess the effects of residuals on wild steelhead within the Hood River, Oregon. For outmigration years 2005 – 2013, we estimated the number of hatchery winter steelhead residuals by combining the marking rate during release year *y* with the recapture probability of PIT-tagged hatchery winter steelhead during year *y+1* (CJS model, Program MARK). The annual rate of residualism was subsequently integrated with additional variables in a multiple regression model (R version 3.1.2) to evaluate the effects of residualism on wild steelhead smolt productivity. The estimated rate of residuals surviving to emigrate the following year was limited (mean = 1.75%, range [0.22% - 5.61%]). Model selection processes (AIC) indicated that environmental conditions may affect both wild and hatchery juvenile steelhead similarly and that the estimated rate of hatchery residualism was positively correlated with wild smolt production (adjusted $r^2 = 0.83$, $p \leq 0.002$). Additional sampling should be conducted to determine the overwinter survival rate and to quantify the non-migratory component of residuals.

Session 3B – Physiology

Variations in Size, Growth and Survival of Hatchery and Wild Columbia River Chinook Salmon in the Northern California Current

Brian Beckman[1], Larissa Rohrbach[2], David J. Tee[l1]

[1]NOAA Fisheries; [2]Anchor QEA

There is increasingly clear evidence that variable ocean conditions are directly responsible for large-scale variation in the return of adult Chinook salmon to the Columbia River. There is also accumulating evidence that variable marine mortality occurs soon after smolts enter the ocean. Finally, inter-annual variation in growth of smolts in the ocean is correlated with adult returns. However, it I not yet clear if and/or how differences in size and growth among smolts in the ocean may subsequently affect differential survival. In this talk we will present data showing differences in size and growth among yearling hatchery Chinook salmon smolts sampled off the Oregon/Washington Coast. We will also present data suggesting that relations between size and growth vary with ocean conditions. Together, these suggest that growth may be food limited in the ocean in some years and that smolts may vary in their ability to exploit food resources across years. Finally, we will compare stock-specific size and growth rate of clipped (hatchery) and un-clipped (wild?) smolts captured at the same time and place in the ocean. The implications of these findings for hatchery rearing strategies and hatchery vs wild interactions in the ocean will be discussed.

Effects of Hatchery-Rearing Practices on Olfactory Imprinting and Homing in Pacific Salmon

Andrew Dittman[1], Darran May[2], Ryan B. Couture[3], David L.G. Noakes[4], and Paul Hoppe[5]

[1]NOAA Fisheries; [2]University of Washington; [3]Oregon Hatchery Research Center/ Oregon State University; [4]Oregon State University; [5]Ocean Associates Inc.

Homing in salmon is governed by the olfactory discrimination of home-stream water. Exposure to the home stream during appropriate juvenile stages is critical for olfactory imprinting and successful completion of the adult homing migration. Hatchery rearing does not necessarily affect homing fidelity but many hatchery rearing and release practices can

dramatically increase the rate of straying by adult salmon returning from the ocean to spawn. In this presentation, we briefly review hatchery practices that may contribute to straying. We then describe examples of how hatchery-rearing practices may affect the olfactory system of juvenile salmon during olfactory imprinting. Specifically, we examined the effects of water source on expression of odorant-receptor mRNA in the olfactory rosettes of steelhead reared in natural stream water vs. well water during the parr-smolt transformation, a sensitive period for olfactory imprinting. Well water is often used in hatcheries to control temperature and limit exposure to pathogens. Specific odorant-receptor mRNA expression increased dramatically during the parr-smolt transformation in steelhead reared in natural stream water relative to fish reared in well water. Differences in odorant receptor mRNA expression were also observed in hatchery and wild Snake River steelhead during their juvenile outmigration through the Columbia River.

Minijacks: Should These Small Fish be a BIG Concern for Chinook Salmon Supplementation Programs?

Donald Larsen[1], Brian Beckman[2], Deborah Harstad[2], Dina Spangenberg[2], Larissa Rohrbach[3], Shelly L. Nance[4], and Abby Tillotson[2]

[1]NOAA Fisheries-Northwest Fisheries Science Center; [2]NOAA Fisheries; [3]Anchor QEA; [4]University of Washington

Male Chinook salmon that precociously mature after just two years of age are often referred to as “minijacks” and are one year younger than more commonly recognized “jacks”. While minijacks are two or more orders of magnitude smaller than anadromous adults, they’re an important component of a diverse life-history portfolio for wild salmonids. Over the past decade we have quantified the proportion of minijacks released from several Chinook salmon hatcheries throughout the Columbia River Basin from both segregated (only hatchery-origin broodstock) and integrated (some natural-origin broodstock) programs and rates varied 10-fold from 7.9 - 71.4% and 4.1 - 40.1% of the males in spring and summer stocks, respectively. Smolt size at release and minijack rate were positively correlated in integrated, but not segregated programs. Rates were significantly higher in integrated compared to the segregated programs despite the fact that most of the integrated programs released smaller fish suggesting that domestication selection for age at maturation has occurred in segregated programs. Consequences of high minijack production including ecological impacts to wild stocks, loss of adult production, domestication selection and altering the accuracy of smolt-to-adult return (SAR) estimates among other factors will be discussed in the context of salmon supplementation and management.

The Core Gene Expression Cascade during the Early Developmental Process Identifies Genetic Mechanisms for Salmonids Captive Breeding

Reiichiro Nakamichi[1], Hirohisa Kishino[2], and Shuichi Kitada[1]

[1]Tokyo University of Marine Science and Technology; [2]The University of Tokyo;

Evidence for lower fitness of captive-reared salmonids in the wild has accumulated in recent years, raising serious concerns for long-term sustainability of wild populations. Comparative studies on the early developmental stages in Atlantic salmon have demonstrated genetic consequences related to energy metabolic, muscle, and immune-related gene expression in farmed/hybrid fish compared with wild. Thus, it is crucial to determine whether these genes are essential to infer the genetic mechanisms. We developed an exploratory graphical modeling approach to extract the key operating interactions rather than describing the entire gene interaction network. We obtained the maximum core expression cascade of 106 genes from a public dataset of farmed Atlantic salmon. An enrichment analysis determined that 13 of the 57 pre-identified farmed/hybrid/wild-differentially expressed genes were included in the core gene cascade (p=6.94×10^{-11}), and some had already reached a plateau before hatch. However, insulin-like growth factor 1 (IGF1), which explains the mechanisms of intended selection for rapid growth, was not included. Our results suggest the mechanisms for the fitness decline caused by captive breeding; that is, accumulated unintended domestication in captivity selects individuals adapted well to the captive environment with non-IGF1-dependent behavioral-related genes which reduce fitness of captive-reared fish in the wild.

Session 3C – Pathogens

Managing Infectious Disease Risks in Salmon and Steelhead Hatcheries and Natural Populations

Maureen Purcell, Gael Kurath, and James Winton; *U.S. Geological Survey*

Much success has been achieved in controlling disease in Pacific salmon and steelhead hatcheries. Many good health practices have been adopted when possible, including improved animal husbandry, enhanced biosecurity measures, regular disease inspections, judicious use of chemotherapeutics, and vertical transmission control. Our knowledge of finfish diseases is largely based on studies of cultured fish and we know comparatively less about diseases in natural populations. In this presentation, I will review some potential risks that hatchery populations may pose to natural populations. For instance, hatchery rearing can facilitate pathogen amplification which, if released, may pose a risk to nearby populations. Similarly, novel host or environmental conditions encountered in the hatchery setting, as well as specific fish management practices, may theoretically drive evolution and possibly alter virulence. The practice of moving fish may introduce pathogens into new geographical areas, with potentially devastating effects on naïve populations. However, much can be done to reduce the risk of hatcheries to natural populations. For instance, the use of local fish stocks in conservation hatcheries reduces the risk from introduction of exotic pathogens and local stocks may be better able to resist endemic pathogens.

The Ecology of Sea Lice in Cobscook Bay: Understanding the Interactions Between Wild and Farmed Hosts

Catherine Frederick, Michael Pietrak, Sarah Barker, Damian Brady, and **Ian Bricknell**; *University of Maine*

Sea lice (*Lepeophtheirus salmonis*) initially infect stocked farmed salmon from sources external to the farm. Once on a farm the lice are able to multiple and can reinfect both wild or farmed fish creating a series of interactions between the parasite and both farmed and wild hosts. Wild fish surveys, sentinel cage deployments and larval transport models are being used to better understand the interactions occurring between this parasite and it farmed and wild hosts. This talk will focus on the results of nearly two years of sentinel cage work. Preliminary results indicate an increasing presence of infection through the late summer and fall with warming water temperatures. Contrary to studies in Europe that observed a cohort of pioneering pre-adults in the spring; the infectious pressure in Cobscook Bay was almost exclusively the infective copepodid stage. The overall risk and intensity of infection observed during the out-migrating smolt window was at levels representative of a sub clinical infection with no physiological impact on the fish. Larval transport models are currently being used to examine potential mechanisms to explain high infectious pressures observed distant to active salmon farms.

Session 3D – Population Dynamics and Modeling

Analyzing Large-Scale Conservation Interventions with Bayesian Hierarchical Models: A Case Study of Supplementing Threatened Pacific Salmon

Mark D. Scheuerell[1], Eric R. Buhle[1], Brice X. Semmens[2], Michael J. Ford[1], Thomas Cooney[1], and Richard W. Carmichael[3]

[1]National Marine Fisheries Service- Northwest Fisheries Science Center; [2]Scripps Institution of Oceanography, UC San Diego; [3]Oregon Department of Fish and Wildlife

A variety of conservation interventions such as habitat restoration and captive breeding have been used to prevent species extinctions. We evaluated the effects of a large-scale supplementation program on the density of adult Chinook salmon *Oncorhynchus tshawytscha* currently from the Snake River basin listed under the U.S. Endangered Species Act. We analyzed 43 years of data from 22 populations, accounting for random effects across time and space using a Bayesian hierarchical model. We found that varying degrees of supplementation over a period of 25 years increased the density of

natural-origin adults, on average, by 0-8% relative to non-supplementation years. Thirty-nine of the 43 year effects were at least two times larger in magnitude than the mean supplementation effect, suggesting common environmental variables play a more important role in driving inter-annual variability in adult density. Residual variation in density varied considerably across the region, but there was no systematic difference between supplemented and reference populations. Our results demonstrate the power of hierarchical Bayesian models to detect diffuse effects of management interventions and to quantify the variability of intervention success. Nevertheless, our study could not address whether ecological factors were more important than genetic considerations in determining the response to supplementation.

Using Stochastic Life Cycle Models to Evaluate the Potential Response of Chinook Salmon Populations to Recovery Actions That Include Hatchery Supplementation

Thomas Cooney[1], Richard W. Carmichael[2], and Billy Connor[3]

[1]National Marine Fisheries Service-Northwest Fisheries Science Center; [2]Oregon Department of Fish and Wildlife; [3]U.S. Fish and Wildlife Service

Stochastic life cycle models can be valuable tools for evaluating potential population performance under alternative future management and environmental scenarios. We have developed stochastic life cycle models for a set of Columbia Basin Chinook populations to assess the projected effects of changes in habitat on population abundance and risk, either in isolation or in combination with actions aimed at other life stages. All of the models are calibrated to recent spawner-to-adult return data. The Grande Ronde spring Chinook population models also incorporate derived empirical relationships for three sequential tributary life history stages. Each of the models includes parameter uncertainty and annual environmental variation. Recovery strategies for three of the populations include hatchery supplementation using locally derived broodstocks. It is generally recognized that properly designed hatchery supplementation programs can contribute to maintaining populations while actions to change key limiting factors take effect, however not without risks. A key uncertainty is at what point in a recovery program, do the long term diversity risks of supplementation outweigh increased total spawner demographic benefits. We use simple indices representative of demographic and diversity risks for summarizing sensitivity analyses of parameter uncertainty and evaluation of projected performance under particular management strategies.

Effects of Salmon Supplementation in Idaho: 20 Years Later, What Do We Really Know?

David Venditti[1], Ryan N. Kinzer[2], and Timothy Copeland[1]

[1]Idaho Department of Fish and Game; [2]Nez Perce Tribe

A common response to declining salmon populations is to supplement natural spawning with hatchery fish, but post-supplementation population responses have never been assessed. We conducted a long-term assessment of supplementation (1992-2014) using a three-phase, control-impact design in two sub-basins. Redd densities (redds per km; RPK) generally increased throughout the study in both sub-basins. From Phase 1 to Phase 3, Salmon sub-basin RPK increased from 3.68 (SD 7.08) to 5.20 (SD 4.43) in treatment streams and 1.02 (SD 1.21) to 3.62 (SD 3.15) in control streams. In the Clearwater sub-basin RPK went from 0.52 (SD 0.88) to 2.29 (SD 2.42) in treatment streams and 0.34 (SD 0.49) to 2.31 (SD 1.57) in control streams. Treatment streams in the Salmon sub-basin displayed a relatively large RPK increase from Phase 1 to Phase 2 (supplementation; 3.68 (SD 7.08) to 5.71 (SD 7.53)) but remained relatively stable during Phase 3 (post supplementation), which could be due to several factors. Both treatment and control streams in the Clearwater sub-basin had almost identical RPK values over all phases, likely due to straying and lack of control structures. Our results suggest supplementation can provide a short-term demographic boost but the effect does not persist after supplementation ceases.

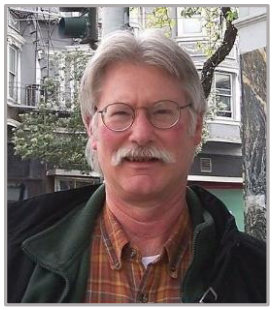
Domestication Selection and Its Implications for Supplementation of Novel Species in the Pacific Northwest

Kevin Goodson; *Oregon Department of Fish and Wildlife*

Evolving technologies over the last several decades have allowed scientists to explore and understand the fitness effects of artificially propagated salmonids interbreeding with wild salmonids. An increasing body of evidence suggests that domestication selection in an artificial environment leads to animals that are not as fit in the natural environment as naturally produced animals. A theoretic genetic model has been widely used to minimize the effects of domestication selection in a mixed population of artificially and naturally propagated salmonids, even though there is little empirical support for the predicted attenuation in fitness loss. The theoretic model's recommendations for the proportion of wild fish collected for propagation and natural spawning of propagated fish are applied to most artificial propagation programs intended to demographically supplement struggling wild salmonid populations in the Pacific Northwest. Proposals have recently been brought forward to apply this salmonid supplementation model to non-salmonids in the Pacific Northwest. I propose that differences in life-history strategies could lead to important differences in optimal supplementation strategies. Should the current salmonid supplementation model be applied to struggling populations of non-salmonids *Entosphenus tridentatus* (Pacific lamprey) and *Acipenser transmontanus* (white sturgeon)?

INTERACTIONS BETWEEN HATCHERY AND WILD SALMONIDS
INTERNATIONAL UNDERSTANDING OF THE RISKS, BENEFITS, AND OPTIONS FOR MANAGEMENT

PRESENTER BIOGRAPHIES



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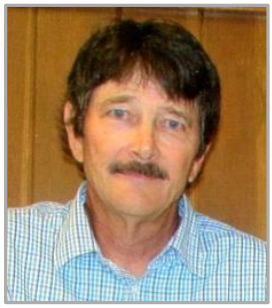
Don currently serves as Science Advisor for the Fishery Resources Division in the Pacific Northwest region of U.S. Fish and Wildlife Service (USFWS). Don received a B.S. in Genetics from the University of California, Berkeley, a M.S. in Fisheries from the University of Washington, Seattle, and a Ph.D. in Genetics from UC Davis. He is a past president of the Genetics Section of the American Fisheries Society and a founding member of the Hatchery Scientific Review Group (HSRG) in the Pacific Northwest. His scientific expertise is the general areas of population genetics, fisheries biology, and their applications to conservation biology and animal breeding.



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Chuck is a mostly-retired aquatic biologist who now lives along the Rogue River in southern Oregon. He has 35 years of experience on a variety of studies of salmon, trout, and their habitats, including 31 years of consulting work done across the Pacific Northwest. Chuck has conducted environmental effects analyses and modeling, designed and implemented aquatic monitoring projects, and helped agencies, tribes, NGOs, and private clients explore ways to maintain or strengthen native fish populations. He served on the Technical Recovery Team for ESA-listed Oregon Coast Coho. The Western Division of AFS awarded him the 2008 Robert Borovicka Conservation Achievement Award, for scientific contributions to fishery conservation.

KATHRYN KOSTOW

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Kathryn has been with Oregon Department of Fish and Wildlife for twenty-five years, working in wild fish conservation and management. Her areas of emphasis include hatchery and harvest risk assessment, population status assessment, and fish biodiversity and biogeography. She holds degrees from the University of Minnesota and the College of Idaho.

NIGEL MILNER

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Nigel was the Head of Fisheries Science in the Environment Agency of England and Wales until 2007. He now works as an Associate Fisheries Scientist for APEM Ltd (Stockport, UK), based at Bangor University (North Wales) where he is an honorary lecturer in fisheries ecology. He has specialized for 35 years in salmonid ecology and population dynamics, with active research interests in modelling habitat relationships, the effects of river flows on migratory fish and in the life histories and evolutionary biology of brown trout. He was instrumental in developing the national salmon assessment methodology, based on Conservation Limits, for England and Wales and recently has been involved in Environmental Impact Assessment of Tidal Barrages, the newest form of renewable energy in UK, with interesting challenges for fisheries.

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Yasuyuki is a senior researcher of the Salmon and Freshwater Fisheries Research Institute, Hokkaido Research Organization (Japan). His current researches are stock assessment, evaluation of hatchery programs, and preseason forecast of chum salmon returning to Hokkaido.

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Kim was a research fish ecologist with Oregon Department of Fish and Wildlife for 31 years and the program leader for the Aquatic Inventories Program since 1989. Kim has a B.A. in Biology from Carleton College and a M.S. in Oceanography from Oregon State University. He led research and monitoring on the status and trends of stream habitat and juvenile salmonids in lower Columbia River and coastal basins, effectiveness of habitat restoration projects in western Oregon, and the relationship of estuarine habitats to salmon productivity and performance. Kim is interested in the protection and restoration of hydrologic and ecological functions of aquatic ecosystems to improve the long-term productivity of salmonid populations in Oregon.

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Jesse is an Associate Professor with the Center for Fisheries, Aquaculture, and Aquatic Sciences (CFAAS) at Southern Illinois University Carbondale where she heads a research team dedicated to aquaculture nutrition and fish physiology. Holding degrees from Western Washington University (B.S., 2002) and Southern Illinois University Carbondale (Ph.D., 2006), Dr. Trushenski leads her team of undergraduate and graduate students, technicians, and researchers in conducting applied and basic research to develop practical solutions for the aquaculture industry.

BILL BOSCH

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Bill holds an M.S. in Computer Science from the University of Washington. Bill has worked for the Yakama Nation Fisheries program on Columbia Basin salmon restoration issues since 1991. He is presently the data manager for the Yakima-Klickitat Fisheries Project.

JASON VOGEL

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Jason has worked in the salmon and steelhead restoration program with the Nez Perce Tribe for the past 17 years. He completed his M.S. at Utah State University and B.S. at University of Idaho. Jason is very interested in looking at the interactions of natural and supplementation fish to help find a balance between conservation, restoration, and harvest mitigation.

ED BOWLES

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Ed has led the fish side of ODFW for the last fourteen years. Some accomplishments include developing and implementing key policies directing native fish conservation and hatchery management, lower Columbia River harvest reform, federal ESA recovery planning, and helping ensure the Federal Columbia River Power System meets their fish conservation and recovery responsibilities. On the marine side, Ed oversees the agency's Marine Program and was the State's lead on developing a system of marine reserves and marine protected areas. Ed represents the west coast as an advisor to the Obama Administration on the National Ocean Policy. He also represented the Governor on the Ocean Policy Advisory Council and is a Commissioner on the Pacific States Marine Fisheries Commission.

SHUICHI KITADA

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Shuichi completed his undergraduate coursework at Faculty of Fisheries, Hokkaido University in 1976. Since that time, he has assessed effectiveness of various hatchery-releases programs and received his Ph. D from the University of Tokyo in 1991. His current research interests include inferring interactions between hatchery and wild fish and developing a high throughput estimation method of the empirical Bayes F_{ST}.

MAUREEN HESS

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Maureen completed her M.S. degree in the School of Aquatic and Fishery Sciences at the University of Washington. She is currently a conservation geneticist with CRITFC where she uses pedigree reconstruction for evaluation of relative reproductive success of natural- and hatchery-origin fish for supplementation and reintroduction programs. She also coordinates parentage-based tagging baselines for steelhead and Chinook salmon in the Columbia River basin, which can be used for monitoring harvest of hatchery stocks, identifying the origin of hatchery strays and kelts, and evaluating the effectiveness of hatchery integration programs.

CHARLES WATERS

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Charles is a graduate student with Dr. Kerry Naish at the University of Washington School of Aquatic and Fishery Sciences. His research aims to characterize genetic adaptation to captivity, identify fitness traits that may respond to genetic change in salmon hatcheries, and evaluate a management approach that may reduce adverse effects of captive rearing. The overall goal of this work is to develop principles that will maximize the success of conservation-focused breeding programs and help rebuild natural salmon populations.

BRICE ADAMS

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Brice received his bachelor's degree in Wildlife Biology from the University of Montana in 1999 and his Master's degree in Biology from the University of Louisiana at Lafayette in 2011. My most recent work has been as a geneticist for the US Fish and Wildlife Service at the Abernathy Fish Technology Conservation Genetics Lab in Longview, WA. My research primarily focuses on population genetics, species identification, and conservation genetics of a variety of taxa found in the Pacific Northwest.

MARC JOHNSON

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Marc serves as technical analyst for the Oregon Department of Fisheries and Wildlife. He received his Doctoral degree in Fisheries from Oregon State University in 2009, after completing his Master's in Ecology at the University of Brasilia and Bachelor's in Zoology, also at OSU. Much of Dr. Johnson's work has focused on the genetic structures of hatchery and wild salmon populations, as well as the genetic bases of olfactory imprinting and homing by these species. Currently, he uses genetic and other tools to study and inform the management of Willamette River steelhead and spring Chinook salmon.

SEWALL YOUNG

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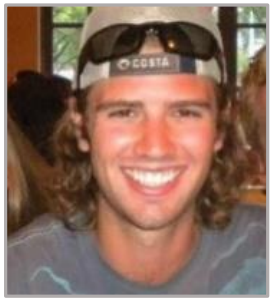
Sewall's interest in fisheries developed while working in a commercial salmon fishery as a teenager. He earned his BS in Wildlife Biology from the University of Montana and MS in Fishery and Wildlife Biology from Colorado State University. He started working at the Washington Department of Fisheries in 1987 where he coordinated sampling of Pacific salmon populations to include in coast-wide Genetic Stock Identification baseline data sets. Currently he is a Research Scientist in the Molecular Genetics Laboratory at Washington Department of Fish and Wildlife where he works on a variety of management oriented genetics/genomics projects.



NEIL F. THOMPSON

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Neil completed his Ph.D. at Oregon State University in 2014 studying rearing density as a driver of domestication selection in hatchery reared *O. mykiss*. He is continuing his Ph.D. work with Mike Blouin as a post-doctoral scholar researching traits under selection for high performance in hatchery environments and potential drivers of domestication in captivity. He received a B.A. in Environmental Biology from the University of Vermont. Between UVM and OSU Neil worked with Vermont Fish and Wildlife as a fisheries technician and sea lamprey treatment landowner liaison.

KYLE HANSON

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Kyle is the Regional Physiologist for the USFWS Pacific Region. He completed a Ph.D. in Biology at Carleton University, where he studied the relationship between physiology and parental care performance in black bass. His current research focuses on the impacts of habitat restoration, aquaculture techniques, and handling practices on the physiology and fitness of fishes.

DANIEL UCHIDA

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Daniel is a native of Chile, where he obtained his B.Sc. in marine biology and M.S. in fisheries at Universidad de Concepción, Chile. In 2002 he moved to the U.S. and graduated with a doctoral degree in fisheries genetics from Oregon State University in 2006. Following postdoctoral positions at Dalhousie University (Canada) and University of Washington, he relocated to Chile and took an assistant professorship in the Dept Zoology at Universidad de Concepción. He founded the GEECLAB ("geek" lab) that uses genetic and genomic data to address ecological, evolutionary, and conservation questions, with emphasis in naturalized Pacific salmon and trout.

NICK SARD

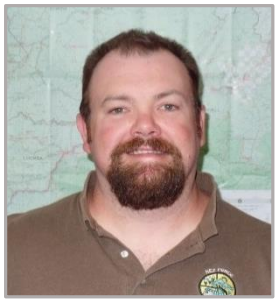
Oregon State University – nicksard@gmail.com

Nick received his Bachelor's and Master's degrees in Biology at SUNY Fredonia in western New York. He is currently a Ph.D. candidate in the Fisheries and Wildlife Department at Oregon State University. Nick uses genetics based approaches to study topics related to fish conservation. Nick's current research addresses questions surrounding the reintroduction of hatchery and natural origin spring Chinook salmon above existing dams.

JOE ZENDT

Yakama Nation Fisheries Program – jzendt@ykfp.org

Joe is a fisheries biologist with the Yakama Nation Fisheries Program and focuses primarily on monitoring and evaluation of anadromous salmonid populations, their habitat, and hatchery/wild fish interactions. He has been employed by the Yakama Nation since 2000 and is based in Klickitat, Washington, in the beautiful Columbia River Gorge. He has a BS degree in Biology from Bucknell University and an MS degree in Fishery Biology from Colorado State University, and has experience working in stream fish sampling, marine fishery monitoring, habitat assessments, forestry/fish interactions, genetic investigations, and fish disease research in variety of places from Virginia to Alaska.



JUSTIN BRETZ

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I am a graduate of the University of Idaho. I began my fisheries career in 1997 with the U.S. Fish and Wildlife Service pulling beach seine in Hells Canyon, Idaho capturing endangered fall Chinook. I have been employed as a fisheries biologist since 1999 and with the Nez Perce Tribe Fisheries Department since 2004. My hobbies include gardening, fishing, hunting, and building acoustic guitars.

BRAD CAVALLO

Cramer Fish Sciences – bcavallo@fishsciences.net

Brad earned a M.S. in Aquatic Ecology from University of Montana and a B.S. in Fisheries from UC Davis. Since joining Cramer Fish Sciences in 2006, Brad has led a growing team of consulting scientists working to help resolve some of California's most vexing fisheries management challenges. His project experiences range from evaluating and planning anadromous hatchery programs to developing simulation models to represent the influence of water project operations and habitat quality on juvenile salmon and steelhead. Brad is currently President of Cramer Fish Sciences and is a Past-President of the California-Nevada Chapter of the American Fisheries Society.

GREG RUGGERONE

Independent Scientific Advisory Board – gruggerone@nrccorp.com

Greg has investigated population dynamics, ecology, and management of Pacific salmon in Alaska and the Pacific Northwest since 1979. Most of his research involves factors that affect growth and survival of salmon in freshwater and marine habitats. For the past 10 years, he has evaluated management of salmon fisheries in Russia, Alaska, British Columbia and California for sustainability using Marine Stewardship Council criteria. He is currently the Chair of the Columbia River Independent Scientific Review Panel and vice-Chair of the Independent Scientific Advisory Board.

TODD PEARSONS

Grant County Public Utility District – Tpearso@gcpud.org

Todd received his B.A. degree in Aquatic Biology from the University of California at Santa Barbara and his M.S. and Ph.D. degrees in Fisheries Science from Oregon State University. Todd is currently the lead hatchery scientist for Grant County PUDs hatchery mitigation programs which span the gamut from captive broodstock programs for critically endangered species and harvest augmentation of one of the healthiest Chinook salmon stocks in the U.S. Todd's research focuses on interactions among hatchery, exotic, and wild fish and how knowledge about interactions can be used to assess and contain risks.

CASEY RUFF

Skagit River System Cooperative – cruff@skagitcoop.org

Casey received his M.S. degree from the School of Aquatic and Fishery Sciences at the University of Washington where he studied the interaction between thermal variation on life history diversity in sockeye salmon and its effects on movement and growth dynamics of rainbow trout in Bristol Bay, Alaska. He is currently the director of the harvest management program within the Skagit River System Cooperative, an agency providing natural resource management services for the Sauk-Suiattle Indian Tribe and the Swinomish Indian Tribal Community. In his current role, he provides technical support for tribal and state fisheries management and salmon and steelhead recovery efforts in the Skagit River basin.

KOH HASEGAWA

Hokkaido National Fisheries Research Institute – hasekoh@affrc.go.jp

Koh has studied the ecological impact of nonnative brown and rainbow trout on native fishes in Hokkaido since an undergraduate student at Hokkaido University. These studies received the prize for young scientists from the Japanese Society of Fisheries Science in 2012. Koh joined the Hokkaido National Fisheries Research Institute, Fisheries Research Agency as a researcher in 2010. Over the last five years, he has studied interactions between wild and hatchery salmon fry including both field work and enclosure experiments.

TEPPO VEHANEN

Natural Resources Institute Finland – Teppo.Vehanen@rktl.fi

Teppo is a senior researcher at the National Resources Institute Finland, Helsinki, Finland. He currently chairs the Technical and Scientific Committee of EIFAAC. He has been working with regulated rivers for more than twenty years, and currently focuses on connectivity issues. His research interests include also Water Framework Directive, especially evaluating biological responses to human influences on the riverine fish community. Related interests include experimental studies, mainly with behavioral issues concerning salmonid fishes.

IAN COURTER

Mount Hood Environmental – ian.courter@mthoodenvironmental.com

Ian is a founding scientist with Mount Hood Environmental (MHE), a family- owned contract research company located in Boring, Oregon. He has served as principal investigator for anadromous fish studies in numerous watersheds throughout the Pacific Northwest and California, including the Willamette, Clackamas, Deschutes, Lewis, Yakima, Methow, Wenatchee, Owyhee, Lower Snake, Upper Columbia, and Sacramento River Basins. Most of this work has been focused on life-history diversity of salmonids and effects of flow and temperature conditions on salmonid survival and production potential.

MAUREEN KAVANAGH

Bonneville Power Administration – makavanagh@bpa.gov

Maureen has worked for the North Carolina Wildlife Resource Commission, the National Park Service in Great Smoky Mountains and Yellowstone NPs, and most recently for the USFWS at the Columbia River Fisheries Program Office. Since 2004, she has been investigating ecological interactions between hatchery and native salmon and trout populations in the Clackamas River Basin, OR. She recently accepted a position with Bonneville Power Administration as a Fish and Wildlife Administrator.

ANNA HAGELIN

Karlstad University – anna.hagelin@kau.se

Anna is a PhD student in fish ecology at Karlstad University, Sweden. Her current research topics include salmonid spawning behaviour, fish migration in regulated rivers and inter specific juvenile competition. Her previous work involved mosquito ecology and tropical stream ecology.

EVA BERGMAN

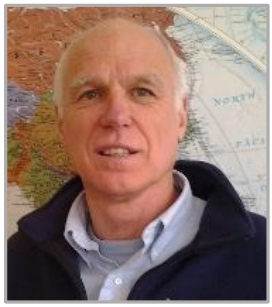
Karlstad University – eva.bergman1868@kau.se

Eva is a professor in aquatic ecology at the Department of Environment and Life Sciences at Karlstad University. She completed a PhD thesis on competitive abilities of percids in eutrophic lakes at Lund University in 1990, continued to work with two large biomanipulation projects until 1998 when she moved to Karlstad University. At Karlstad University she has been working with fish ecology in streams focusing on 1) how stream wood affects brown trout (Salmo trutta) and 2) ecological prerequisites for wild and quality of farmed salmon and trout in ecosystems with regulated rivers.

DANIEL BOTTOM

NOAA Fisheries – Dan.bottom@noaa.gov

Dan has served as a fishery research biologist in state and federal government for 38 years. Since joining NOAA's Northwest Fishery Science Center in 1999, he has led an interdisciplinary team investigating the ecology of juvenile salmon in the Columbia River estuary. His research interests include the estuarine life history and ecology of Pacific salmon species, ecosystem responses to estuary restoration, and the history of ideas in fisheries management. Dan is a member of the Expert Regional Technical Group, established to assess the benefits of proposed estuary restoration projects to the recovery of at-risk Columbia River salmon.



ERIC KNUDSEN

Prince Sound Science Center – eericknudsen@gmail.com

Eric earned his Ph.D. in wildlife and fisheries science from Louisiana State University. He has 40 years of experience in fisheries and wildlife science and management with the USGS and now as a consultant. Much of his career has been focused on Pacific salmonids in Alaska and the Pacific Northwest. Eric is a Past President of the Washington–British Columbia Chapter and the Western Division, American Fisheries Society, is a co-Founder and current President of Ecologists Without Borders, and currently manages the Hatchery-Wild Interactions Study.

CHRISTOPHER TATARA

NOAA Fisheries – chris.p.tatara@noaa.gov

Chris is a research fisheries biologist on the Behavioral Ecology Team at NOAA's Northwest Fisheries Science Center. He earned a B.S. in Fisheries Biology from U.C. Davis in 1993, and a Ph.D. in Ecology/Toxicology from the University of Georgia in 1999. Chris conducts field and laboratory research on the behavioral ecology of steelhead, including differences between hatchery and wild populations, ecological interactions between hatchery and wild fish, and the environmental and genetic mechanisms that account for differences and influence interactions. Chris collaborates on two research projects studying the effectiveness steelhead hatcheries.

CHARLES ERDMAN

University of Idaho – cerdman@uidaho.edu

Charles is a master's student in the Department of Fish and Wildlife Sciences at the University of Idaho where he is advised by Christopher Caudill. His research focuses on the post-release movement and distribution of recycled steelhead in the Willamette River basin and how marine growth influences life history variability in steelhead. Prior to graduate school, Charlie was employed by The Nature Conservancy where he examined larval sucker response to large-scale wetland restoration in the Klamath Basin, Oregon.

PHILIP SIMPSON

Oregon Department of Fish and Wildlife – philip.c.simpson@state.or.us

Phil received a B.A. in Business Management from Pacific University in 1996 and later received his B.S. in Biology from Southern Oregon University in 2002. In 2008, he received his M.S. degree from Delaware State University studying habitat use patterns of Delaware River Atlantic sturgeon. Phil spent 3 years working as the ODFW North Coast Habitat Restoration Biologist and is currently the Project Leader for the ODFW Hood River Research Program focused on life cycle monitoring of steelhead and spring Chinook.

BRIAN BECKMAN

NOAA Fisheries – brian.beckman@noaa.gov

Brian is a research biologist with the Northwest Fisheries Science Center, National Marine Fisheries Service in Seattle. He has a BS from Oregon State, a MS from the State University of New York, Stony Brook and a PhD from the University of Washington. He has worked on growth and smolting of juvenile coho and Chinook salmon throughout the Pacific Northwest and has relatively recently transitioned into the study of the marine growth of juvenile salmon.

ANDREW DITTMAN

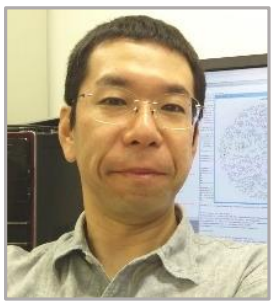
NOAA Fisheries – andy.dittman@noaa.gov

Andy is a research biologist with the National Marine Fisheries Service in Seattle. He received his B.A. from Dartmouth College and his Ph.D. from the University of Washington. After post-doctoral fellowships at NOAA and the University of California, Berkeley, he joined the Environmental Physiology Program at the Northwest Fisheries Science Center, where a major focus of his research is olfactory imprinting and homing in Pacific salmon. Current studies include development of molecular assays for imprinting and experiments to determine the timing of imprinting and appropriate hatchery rearing, transport and release strategies to minimize straying in salmonids.

DONALD LARSEN

NOAA Fisheries – don.larsen@noaa.gov

Don received his PhD in Fisheries from the University of Washington, Seattle. He has worked at the Northwest Fisheries Science Center in Seattle for the past 25 years, the majority of that time as a Research Fisheries Biologist. His research explores physiological regulation (with an emphasis in endocrinology) of salmonid life history. Recent studies have focused on examining the physiological differences between hatchery and wild fish and understanding the interaction of genotypic and environmental drivers of smoltification and early male maturation in Chinook salmon and Steelhead trout.



REIICHIRO NAKAMICHI

Tokyo University of Marine Science and Technology – r-nkmc@kaiyodai.ac.jp

Reiichiro completed his Ph.D. in the Graduate School of Agriculture and Life Sciences at the University of Tokyo, where he studied bioinformatics and statistical genetics. Since graduate school, he has worked on the methodologies of QTL analysis, GWAS and gene expression analysis. His current interests include the application of gene regulatory network analysis in order to elucidate the mechanisms of salmon adaptation to climate change and hatchery environment.

MAUREEN PURCELL

U.S. Geological Survey – mpurcell@usgs.gov

Maureen is currently employed as a Research Microbiologist at the Western Fisheries Research Center – US Geological Survey in Seattle, WA. Maureen received her B.S. in Zoology from Washington State University in 1993, her M.S. in Zoology from the University of Maine in 1997 and Ph.D. in Aquatic and Fishery Sciences from the University of Washington in 2005. Her current research focuses on a range of pathogens that infect salmonid and clupleid fishes, including *Renibacterium salmoninarum, Icthyophonus* sp., infectious hematopoietic necrosis virus and piscine orthoreovirus. In addition to research, she actively engages in training and technical outreach activities.

IAN BRICKNELL

University of Maine – ian.bricknell@umit.maine.edu

Ian accepted the post of Libra Professor of Aquaculture Biology at the University of Maine and in 2009 was appointed as the first Director of the Aquaculture Research Institute. Since arriving in the USA he has established a new aquatic animal disease research group. He has expanded his research interests to include lobster health and he is committed to helping the working waterfront in Maine to ensure a sustainable and dynamic aquaculture industry in Maine.

MARK SCHEUERELL

NOAA Fisheries – Mark.Scheuerell@noaa.gov

Mark is a research fisheries biologist at NOAA's Northwest Fisheries Science Center in Seattle, and an affiliate assistant professor in the School of Aquatic and Fisheries Sciences at the University of Washington. He has a B.S. in Zoology from the University of Wisconsin-Madison, an M.S. in Fishery and Aquatic Science from Cornell University, and a Ph.D. in Zoology from the University of Washington. Mark's research focuses primarily on analyses of complex, multivariate data sets; some of this work is retrospective, but much of it is specifically aimed at forecasting future dynamics.

THOMAS COONEY

NOAA Fisheries – Tom.Cooney@noaa.gov

Tom is a research biologist with the Northwest Fisheries Science Center, National Marine Fisheries Service. He has a B.A. from Humboldt State University and a M.S. in Biological Oceanography from the University of Hawaii, Manoa. Prior to joining the NWFSC, he worked for WDFW and for the Quinault Tribal Dept. of Natural Resources. He was co-chair of the NOAA Interior Columbia Basin Technical Recovery Team and is a member of the Pacific Salmon Commission Sentinel Stocks Committee. His primary research interests involve developing and using life cycle models to evaluate salmonid recovery and escapement management strategies.

DAVID VENDITTI

Idaho Department of Fish and Game – david.venditti@idfg.idaho.gov

David worked for the USGS as a Fisheries Research Biologist working on fall Chinook Salmon early rearing habitat requirements in the Columbia River and juvenile fall Chinook migration behavior through main stem Snake River hydroelectric impoundments. In 2000, he joined the Idaho Department of Fish and Game's research section and has been involved in Chinook Salmon conservation programs ever since. He began with IDFG on a captive rearing program, and then in 2004, he moved on to coordinating a long-term supplementation research project. This program began in 1991 and wrapped up data collection in 2014.

KEVIN GOODSON

Oregon Department of Fish and Wildlife – Kevin.W.Goodson@state.or.us

Kevin has been the Conservation Planning Coordinator for Oregon Department of Fish and Wildlife's Fish Division for almost 12 years. In addition to developing and helping implement conservation plans for Oregon's native fish, Kevin has worked in and around the hatchery-wild issue for over 30 years – first as a hatchery technician, then a field biologist during the "clubbing incident," and through recent litigation over hatchery impacts.