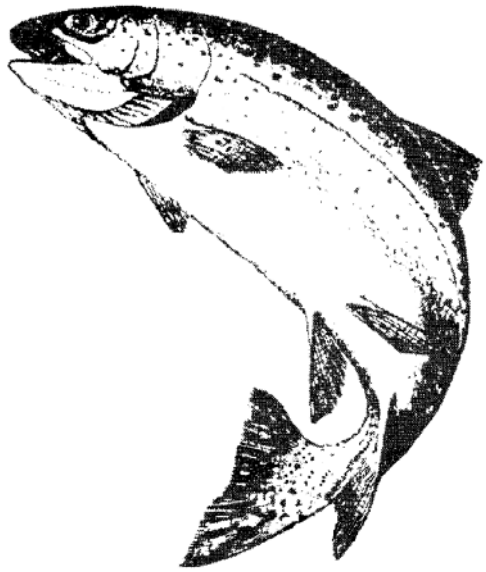
***SUMMARY OF***
***THE TWELFTH***

# *PACIFIC COAST STEELHEAD MANAGEMENT MEETING*



**March 9-11, 2010**
**Eagle Crest Resort - Redmond, Oregon**

***Sponsored by:***

***Pacific States Marine Fisheries Commission***

***&***

***U.S. Fish and Wildlife Service***

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# Pacific Coast Steelhead Management Workshop

**March 9-11, 2010**
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## I. Summary

The Pacific States Marine Fisheries Commission (PSMFC), with support from the U.S. Fish and Wildlife Service Sport Fish Restoration Program, sponsored the 12th workshop on steelhead (*Oncorhynchus mykiss*) management. The workshop, held in Redmond, Oregon was attended by some 110 Pacific Coast fisheries managers, researchers and other interested parties from the states of Alaska, California, Washington, Idaho, and Oregon.

Topics for the workshop included:

- steelhead stock status and the Endangered Species Act
- re-introduction of steelhead
- residency/anadromy in *o. mykiss*
- reproductive success and related genetic studies of steelhead
- adult steelhead abundance monitoring
- movement in time and space
- new ideas and challenges to current management doctrines

The workshop was structured as a series of individual presentations by topic area or contributed paper session, followed by a panel discussion and questions from the audience. The meeting allowed steelhead managers and researchers to discuss common problems and to share insights into possible solutions on a coast-wide basis.

The contributed papers session covered the value of repeat steelhead spawners to population persistence using age-structured modeling, the life history diversity and abundance of Kamchatka steelhead, catastrophic overescapement of salmon, and steelhead and cutthroat hybrids. In addition, a poster session was held on various topics including Calcein mark retention in Chinook salmon and steelhead trout fry, using underwater video technology to monitor fish runs, acoustic monitoring through the Lower American River and Sacramento San-Joaquin Delta system, and John Day River Steelhead: Lost in the Columbia.

Abstracts from all the sessions were prepared by the speakers and are included in this summary. The PowerPoint presentations given by the speakers can be viewed at the PSMFC website: http://www.psmfc.org/steelhead/past-2010.html.

Members of the Workshop Steering Committee were:

Bob Leland, State of Washington, **Chair**
Terry Jackson, State of California
Roger Harding, State of Alaska
Alan Byrne, State of Idaho
Stephen Phillips, Pacific States Marine Fisheries Commission
Kevin Goodson, State of Oregon
Nick Gayeski, Wild Fish Conservancy
Grant Kirby, Northwest Indian Fisheries Commission
Carol Coyle, State of Alaska

## II. Steelhead Stock Status Review by Ju490risdiction

Session Chair: Roger Harding, Alaska Department of Fish and Game

### A. California

Terry Jackson, California Department of Fish and Game

California has six Distinct Population Segments (DPS) of steelhead as determined by the National Marine Fisheries Service (NMFS). Four of the six remain listed as threatened (Northern California, Central Valley California, Central California Coast, and South-Central California Coast), one remains as endangered (Southern California) and one remains not warranted for listing (Klamath Mountains Province). The two northern DPSs include summer, winter, and half-pounder runs of steelhead, while the remaining DPSs include only winter steelhead. Historically California had substantial steelhead populations, including runs of 4,000 to 20,000 steelhead in southern California streams. In general, wild steelhead stocks appear to be stable at low levels.

Monitoring efforts in California are, in general, currently inadequate to properly assess population abundance, and trends and conclusions about stock status are tenuous. Only a few streams are monitored for adult returns. Where we have juvenile abundance or density data we do not know how these data relate to the status of the adult populations. The statewide Steelhead Restoration and Management Plan is currently being updated.

Several monitoring plans, however, are being developed and California has a statewide steelhead fishing report card program for harvest estimates and trend assessments. A geographic distribution dataset of steelhead and resident rainbow trout throughout California has been established. California's Passage Assessment Database (PAD) Barrier Analysis Tool for prioritizing barrier restoration/removal in the coastal watersheds based on the quantity and quality of potential salmon and steelhead habitat available upstream, is fairly functional and has provided slides for each of the DPSs in my presentation. Lack of water flowing down streams and access above barriers remains the primary limiting factors for California steelhead. Efforts to modify and remove barriers, specifically south of San Francisco, have been a focus.

The development of a comprehensive steelhead monitoring plan has been initiated for California's Central Valley, and will include spatially and temporally balanced sampling protocol that will allow development of statistically defensible population estimates. The plan will incorporate an adaptive management strategy, develop a standardized database structure, and implement standardized reporting techniques. This plan is slated to be complete this year.

Data gathered from the Steelhead Fishing Report-Restoration Card program (http://www.dfg.ca.gov/fish/Fishing/Monitoring/SHRC/index.asp) shows that steelhead anglers continued to release the majority of their steelhead (including hatchery steelhead). Because of concern that hatchery steelhead are straying and spawning

with wild stocks, angling regulations have been modified to allow 2 hatchery steelhead daily with 4 in possession for many streams, and regulation efforts are underway to expand this statewide. Wild steelhead are no longer harvested in any river in California.

## B. Oregon

Kevin Goodson, Oregon Department of Fish and Wildlife

Six distinct population segments (DPSs) of steelhead have been defined in Oregon by NOAA Fisheries. Four of the DPSs are listed as threatened under the Endangered Species Act. Recovery plans are either completed, near completion or under development for all four listed DPSs in Oregon. These plans have defined the current status of steelhead in these areas. The Mid-Columbia DPS appears to show a continuing declining trend, although fishery reports suggest a strong return for the 2010 spawning season. In the Deschutes and John Day populations of the Mid-Columbia DPS the high incidence of hatchery steelhead from Snake River hatcheries is concerning. In the Lower Columbia River and Upper Willamette DPSs winter steelhead returns have remained low, though 2010 appears to be an improvement. The Oregon Coast DPS does not appear to be showing a declining trend, and the Siletz summer steelhead population has maintained improved escapements since a change in management at Siletz Falls prevented winter steelhead from competing with the summers. In the Klamath Mountains Province, both summer and winter steelhead show no signs of decline.

## C. Idaho

Alan Byrne, Idaho Department of Fish and Game

Snake River adult steelhead status fluctuates with migration corridor habitat and flow conditions. Idaho historically produced about 55% of the total summer steelhead in the Columbia River basin. An average of 70,000 wild adult summer steelhead entered the Snake River during the 1960s, based on Ice Harbor Dam counts. During this period, nearly all steelhead were wild and were the most numerous anadromous fish returning to the Snake River Basin. The documented thirty-year decline of Snake River steelhead led to their listing as threatened in October 1997, pursuant to the federal Endangered Species Act. Development of the Federal Columbia River Power System (FCRPS), particularly the four dams and reservoirs on the Lower Snake River, is considered to be the primary factor in the decline of Snake River steelhead. About 60% of the historical steelhead habitat in Idaho is still available, primarily in the Salmon and Clearwater river drainages. About 30% of Idaho's existing steelhead habitat is included within designated wilderness or wild and scenic river corridors. There is a mix of natural and hatchery steelhead production strategies in Idaho, ranging from wild refugia to large-scale hatchery programs to provide harvest opportunities. Areas managed for wild steelhead include the Lochsa and the Selway river drainages of the Clearwater River, the Middle Fork and South Fork drainages of the Salmon River, Rapid River, tributaries of the Salmon River downstream of the MF Salmon River, and tributaries of the Clearwater

River downstream of the SF Clearwater. Since the 1960s, the composition of the steelhead run entering Idaho has changed. The proportion of hatchery origin steelhead has steadily increased due to declining returns of natural fish and development of hatcheries. During 1960's, the Snake River steelhead run was essentially 100% wild. Since 2000 the run has averaged nearly 14% (26,265 fish) naturally produced steelhead. The mitigation goal for hatchery origin fish, to provide for angler harvest, is 80,000 steelhead at Lower Granite Dam. This goal has been exceeded every year since 2000 and has averaged 146,300 adipose clipped steelhead. The 2009-2010 run is the largest counted at Lower Granite Dam. During the fall migration period a total of 312,430 steelhead (42,100 wild) passed Lower Granite Dam. More than 57,000 hatchery origin steelhead were harvested in Idaho during the fall 2009. Only hatchery steelhead with a clipped adipose fin may be kept in Idaho.

## D. Washington

Jon Anderson, Washington Department of Fish and Wildlife

Washington State steelhead are classified into seven Distinct Population Segments (DPSs) by the federal National Oceanic and Atmospheric Administration (NOAA). Some DPSs are limited to Washington. However, most include bordering states such as Oregon and Idaho as well as British Columbia, Canada.

The Olympic Peninsula and Southwest Washington DPSs are considered *Not Warranted* for listing under the Endangered Species Act (ESA) by NOAA.

The Lower and Middle Columbia River DPSs and Snake River Basin DPS are listed as *Threatened*. The Upper Columbia River ESU was down-listed from *Endangered* status to *Threatened* by NOAA in June 2009.

In May 2007, steelhead stocks in the Puget Sound DPS were listed as *Threatened* under ESA. WDFW and the Puget Sound Treaty Tribes are in the process of finalizing the harvest management component of a Resource Management Plan for this DPS.

Recent data on total run size of wild steelhead show a continuing decline in Puget Sound stocks, and short-term declines in the Olympic Peninsula and Southwest Washington DPS populations. Lower Columbia winter and summer stocks demonstrate a cyclic decline in the past six years.

Wild summer steelhead stocks in the Yakima River of the Middle Columbia River DPS, and the Methow and Okanogan rivers in the Upper Columbia River DPS have shown an increasing trend over the past 12 years. Their numbers mirror the upward trend in the passage of wild steelhead over Bonneville and Priest Rapids dams on the Columbia River and over Ice Harbor Dam on the Snake River.

To restore and preserve this important resource, WDFW developed the Statewide Steelhead Management Plan (SSMP), which was approved by the Washington Fish and

Wildlife Commission in March 2008. This document provides a framework of policies, strategies, and actions for steelhead management throughout the state and is designed to guide state fish managers as they work with tribal co-managers and local fish-recovery groups to develop strategies for managing steelhead populations at the local/regional watershed level.

In conclusion, WDFW and co-managers will continue to work through this important multi-phase local/regional watershed level planning process with public stakeholders in order to restore and maintain the abundance, distribution, diversity, and long-term productivity of Washington's wild steelhead and their habitats.

## E. Alaska

Brian Marston, Alaska Department of Fish and Game

Steelhead *Oncorhynchus mykiss* are found in streams and rivers from Cape Muzon in Southeast (SE) Alaska to the Aleutian Peninsula of Southcentral (SC) Alaska at Port Moeller. A total of 4,202 km of known steelhead waters are documented within 319 drainages. Many streams in the state have not been surveyed for steelhead presence or absence. The vast majority of runs are small containing fewer than 200 adults, while the largest known population, in the Situk River, averages 7- 9,000 adult kelts. Kodiak Island and the Kenai Peninsula also have significant runs. Significant sport fisheries occur in ~ 20 drainages. Yearly adult fish stock assessments are limited to 9 selected streams surveyed with snorkel counts, and 6 other selected streams surveyed with weirs. These yearly assessments are done in selected streams in all the significant sport fishery areas and are distributed throughout the known range of steelhead in Alaska. Streams assessed in SE Alaska were at or slightly below long term median counts in 2008 and 2009 after descending from historic high counts in the mid 2000's. SC Alaskan streams were at or above median counts in 2008 and 2009 after several years below average in the mid 2000's. Length attributes measured on the Situk River, were greater than 30% of the steelhead in Alaska are caught, have not decreased. Sport fisheries on wild fish are conservatively managed with yearly harvest limits of 2 fish and minimum size limits, or as catch and release only waters. The majority of steelhead in Alaska are from wild runs, but one small steelhead hatchery exists in the state at Ketchikan Creek, that releases ~ 1500 smolts annually. Sustaining quality wild steelhead fisheries, limiting habitat degradation, and repairing damaged habitats remain the primary objectives of steelhead management in Alaska. Management policy and regulation is focused by preemptive management planning to avoid impacts to steelhead habitats and maintain the current abundance, age, and size attributes of wild steelhead populations. Sport fishery catch of steelhead in 2008 was the highest yet recorded, while harvest remains low. Reported incidental harvests from commercial salmon fisheries, and subsistence harvest reports for steelhead suggest that these harvests in Alaska are low. Current abundances assessments of steelhead in selected streams of Alaska appear to be within normal variation; some SE streams have declined from recent historically high abundance, while SC streams are at average or peak

abundance after recent low counts. Current conservative regulations provide for sustainability of steelhead stocks while allowing for a limited sport fishery.

## F. Progress Report on Developing Viability Criteria for Threatened Puget Sound Steelhead

Jeff Hard, NOAA Fisheries

We briefly summarize the status of threatened Puget Sound steelhead and outline the approach the Technical Recovery Team is using to develop viability criteria to assist recovery of this Distinct Population Segment (DPS). The approach has two primary objectives: 1) identify Demographically Independent Populations and Major Population Groups within the DPS, and 2) assess the viability of these populations, groups, and the DPS as a whole, using Viable Salmonid Populations criteria. We describe the Team's progress toward these objectives and key features of a few of the tools that the Team is using to develop viability criteria for recovery.

## III. Reintroduction of Steelhead

Session Chair: Megan Hill, Portland General Electric

### A. Documenting *Onchorhynchus mykiss* Life Histories in Rattlesnake Creek and White Salmon River Prior to the Reintroduction of Anadromous Fish Above Condit Dam

Brady Allen, U.S. Geological Survey

From 2001 through 2005, we documented the life history characteristics of rainbow trout *Oncorhynchus mykiss* populations prior to anadromous fish reintroduction in the White Salmon River with the pending removal of Condit Dam in 2010. The dam has blocked upstream migration of anadromous fish at river kilometer 5.1 since 1913. To document the existing *O. mykiss* life history diversity, we combined radio and passive integrated transponder (PIT) tagging technologies. Radio tagging ($n$ = 64) was performed in the mainstem White Salmon River from the reservoir above Condit Dam through the likely zone of anadromous fish recolonization (rkm 5.1 – 19.7). To record movement and growth patterns in Rattlesnake Creek and the White Salmon River, an instream PIT-tag interrogation system was installed in Rattlesnake Creek at rkm 0.2, and PIT tagging ($n$ = 4,856) was conducted in several reaches. The *O. mykiss* in Rattlesnake Creek and White Salmon River exhibited a wide spectrum of migratory tendencies including resident, fluvial, adfluvial, and anadromous life histories. Our radio-tagging and PIT-tagging efforts in Rattlesnake Creek and the White Salmon River showed that important linkages exist between the mainstem White Salmon River and tributary populations of *O. mykiss.* Some evidence showed that the connection to the Columbia River and the Pacific Ocean has not been severed, which indicates that rainbow trout above Condit Dam have potential to be an important source for reestablishing the steelhead life history to the upper White Salmon River with the removal of Condit Dam. The results of these projects were used to assist management agencies in developing reintroduction plans for anadromous salmonid and management plans to meet restoration goals. In preparation for the restoration of fish passage to the historically anadromous portion of the White Salmon River, the Condit Workgroup was formed to create a fish salvage and anadromous salmonid re-introduction plan. Members of this group, which first met on 13 February 2007, included: U.S. Geological Survey (USGS), Yakama Nation (YN), U.S. Fish and Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA), Washington Department of Fish and Wildlife (WDFW), and PacifiCorp. Recommended options for steelhead reintroductions from the Condit Workgroup are being incorporated into NOAA's Endangered Species Act recovery plans for the White Salmon River populations of Middle Columbia River steelhead.

### B. Reintroduction of Steelhead to the Upper Deschutes River

Megan Hill, Portland General Electric

Anadromous fish were extirpated from the upper Deschutes watershed above the three dams of the Pelton Round Butte hydro project (rkm 100) in the 1960s. Original dam

construction included a fish passage system; however, due to bottom withdrawal, confusing reservoir currents and temperatures did not attract smolts to the forebay and fish collector. To remedy the poor attraction currents, and to manage downstream water temperatures, complementary selective water withdrawal (SWW) and fish collection systems were constructed in the Round Butte forebay. The SWW became operational in December 2009. It is anticipated that surface withdrawal will improve reservoir guidance currents and temperatures to attract migrating fish through the reservoir. In anticipation of fish passage, steelhead fry have been out-planted in the tributaries each spring since 2007. Monitoring studies are underway to determine steelhead rearing success, smolt out-migration and survival through the reservoir. I will present an overview of the SWW system, as well as a summaries of the reintroduction strategy and monitoring studies.

### C. Biological Evaluations of Collectors and Trap-and-Haul Programs for Steelhead Reintroduction Efforts on the Cowlitz and Toutle Rivers

Tobias Kock, U.S. Geological Survey

Steelhead reintroduction efforts often include collection sites and trap-and-haul programs to move juvenile or adult fish around dams, water diversions, or other man-made obstacles. Reintroduction efforts for winter steelhead runs in the upper Cowlitz River and North Fork Toutle River systems include juvenile and adult collectors on the Cowlitz River and an adult collector on the North Fork Toutle River. Fish collected at these sites are transported around dams and released to resume migration to the ocean (juveniles) or spawning sites (adults). Our findings on the North Fork Toutle River have shown that collection structures for adult steelhead have low collection efficiencies which may limit the number of fish that are annually transported. Additionally, we found that factors such as the location of release sites and the origin (natural or hatchery) of transported adult steelhead on the Cowlitz River are important determinants in the spatial distribution of fish during the spawning period. Our evaluations of juvenile collection devices at Cowlitz Falls Dam have identified factors that affect the collection success of surface-oriented juvenile steelhead. These findings illustrate how the behavior of juvenile and adult steelhead can affect the efficacy of collection and trap-and-haul programs.

### D. The Reintroduction of Late-Run Winter Steelhead into the Upper North Fork Lewis River, Washington, Using F1 Wild Broodstock Hatchery Adults

Rich Turner, NOAA Fisheries

Access to historical habitat in the upper North Fork Lewis River in Southwest Washington State by native late-run winter steelhead has been blocked since June 1930 by the construction of Merwin Dam and later Yale, and Swift hydro-electric dams. The facilities received new Federal Energy Regulatory Commission operating licenses in June 2008, requiring mitigation measures including the reintroduction of spring Chinook, coho, and late-run winter steelhead into 174 miles of historical habitat and

hatchery production to support fisheries. Beginning with the 2009 brood year, up to 50 wild late-run winter steelhead adults will be collected each year for broodstock. Wild late-run winter steelhead broodstock will be collected from the fish trap at the base of Merwin dam, through seining operations in the lower North Fork Lewis River and through harvest by preselected sport anglers. Individual unmarked adult winter steelhead broodstock will be tagged with Passive Integrated Transponders and Floy tags, and a genetic sample will be taken to identify the steelhead's origin. Only unmarked steelhead identified as originating from the North Fork Lewis River will be targeted for broodstock. The production goal is to release up to 50,000 1+ smolts that will be uniquely marked, and released downstream of Merwin Dam. Upon their return as adults, they would be transported and released upstream of Swift Dam, thus constituting the adult reintroduction program. In 2009, the program was constrained by a number of factors, including the time needed to process genetic samples, broodstock collection goals, the use of wild steelhead of mixed origin, having enough ripe males and females to spawn together, collecting and spawning broodstock in May, and achieving 1+smolts by the release date goal. The presentation will describe the adjustments that will be implemented for broodyear 2010.

## IV. Residency/Anadromy in *Oncorhynchus mykiss*

Session Chair: John Dunham, U.S. Geological Survey;
John McMillan, NOAA Fisheries; Chris Jordan, NOAA Fisheries

### A. Linkages Among Physical Habitat Characteristics and Life History Patterns and Genetic Variation in Hood Canal *Oncorhynchus mykiss* Populations

Barry Berejikian, NOAA Fisheries

In 2006, an ecosystem-scale experiment was initiated in the Hood Canal to determine the effects of steelhead (*Oncorhynchus mykiss*) hatchery programs on ESA-listed natural populations. The study involves monitoring abundance, genetics and life history diversity in three supplemented and four non-supplemented natural populations before, during, and after hatchery fish begin spawning in any of the streams. This presentation includes findings from the 'pre-supplementation' phase of the project aimed at characterizing the natural condition of Hood Canal *O. mykiss* populations. Hood Canal streams vary widely in flow, temperature and geologic profiles. East side lowland streams (Big Beef Creek, Dewatto River, Tahuya River) are typified by lower flows (particularly in the summer) higher temperatures and a decreasing flow through the winter and spring. Western streams draining the Olympic mountains (Little Quilcene, Dosewallips, Duckabush, Hamma Hamma, and Skokomish) are steeper, colder, have increasing spring flows associated with glacial or snow melt run-off, and all but one (Skokomish) have barriers to anadromous fish migration. Adult abundance (based on redd surveys) has been fairly low and stable in all streams over the past 15 years and is strongly positively correlated with stream length ($R^2 = 0.87$), but not mean flow ($R^2 = 0.24$) or annual cumulative temperature units ($R^2 = 0.01$). Streams without barriers to anadromous migration support adult populations that are nearly twice as dense (redds per km) as populations with anadromous barriers that support rainbow trout populations above and below the barriers. Otolith microchemistry data suggest that steelhead females produced nearly all of the *O. mykiss* parr collected during the summer in non-barrier streams, whereas resident rainbow trout females produced significant proportions of parr in the anadromous-accessible reaches of the barrier streams (Hamma Hamma, Duckabush, and Dosewallips). We hypothesize that competition from resident populations in barrier streams may limit the productivity of steelhead under current conditions of low marine survival. Analyses of microsatellite DNA data show significant genetic differentiation between east side and west side populations. The Hamma Hamma River shows further differentiation from other west side populations. Offspring of resident and anadromous *O. mykiss* within the same river were genetically more similar to each other than to samples of the same life history type from different rivers.

## B. Evidence for the Influence of Environment on Expression of Female Anadromy and Individual Condition on Male Residency in *Oncorhynchus mykiss*

John McMillan, NOAA Fisheries

*Oncorhynchus mykiss* (rainbow trout) displays two different life histories that co-exist in many watersheds. Anadromous 'steelhead' trout migrate to sea where individuals generally grow to a large size before returning to freshwater. Resident rainbow trout complete their entire life cycle in freshwater where they typically mature at a smaller size. Occurrence of these two life histories is expected to be strongly influenced by spatial variation in freshwater conditions linked to growth, survival, and reproductive success. We evaluated this premise by examining patterns of occurrence of female anadromy and the influence of water temperature on resident male condition and maturity. We studied *O. mykiss* in the John Day River, a large (>25,000km$^2$) watershed in northeast Oregon. To identify occurrence of female anadromy (steelhead), we determined maternal origin of juveniles using strontium to calcium ratios in the otolith primoridia. Occurrence of these juveniles was assumed to mirror occurrence of female steelhead. A logistic regression model using stream size as the explanatory variable correctly predicted female anadromy with a moderate level of accuracy (68%). We developed a logistic regression model to predict freshwater maturity of males based on growth (length at age 1+) and whole body lipid content. To link individual condition to ambient conditions, we tested for differences in growth and lipids differed between streams with warm and cold thermal regimes (annual degree-days). Larger males with higher lipid levels had a greater probability of maturing as a resident at age-1+ than smaller males with lower lipid levels. Overall, 40 % of the sampled fish were maturing and 80 % of those maturing fish had a length greater than 99 mm and whole body lipid content greater than 4 %. Growth was greater in warm streams and whole body lipid content higher in cold streams. In sum, we were able to predict 1) the occurrence of anadromous females across broad environmental gradients, 2) resident male maturity based on measures of individual condition, and 3) determine that environment exerted a strong influence on individual condition. Results of this work suggest environmental changes linked to natural variability, restoration, or climate change can act to modulate abundance of steelhead or rainbow trout by influencing life history expression.

## C. Partial Migration in *Oncorhynchus mykiss* from the Lower Klamath River Basin

Brian Hodge, Humboldt State University

We examined life form and life history of wild *Oncorhynchus mykiss* in the lower Klamath River Basin, a fishery that supports the largest steelhead population in California. Analysis of otolith strontium isotopes ($^{87}Sr/^{86}Sr$) was used to retrospectively determine maternal origin (anadromous vs nonanadromous) and migratory history (anadromous vs nonanadromous) of 65 fish. In addition, scale pattern analysis was used to determine age, growth, and life history of O. *mykiss* captured throughout the basin between August 2007 and April 2009. Sympatrically occurring anadromous (steelhead) and nonanadromous (rainbow trout) forms of O. *mykiss* were observed in

the mainstem Klamath and major tributaries. Further, we observed rainbow trout of steelhead maternal origin, and steelhead of rainbow trout maternal origin. Our findings may be of interest to those considering the biological implications of dam removal on the Klamath River.

## D. Influence of Resident Rainbow Trout on Abundance of Sympatric Steelhead in the Upper Yakima Basin

Ian Courter, Cramer and Associates

Precipitous declines in steelhead abundance along the Pacific Coast have lead to 11 steelhead population listings under the U.S. Endangered Species Act, and endangered designation by the Committee on the Status of Endangered Wildlife in Canada. In contrast to steelhead declines, dense populations of sympatric resident rainbow trout persist in many streams where steelhead abundance is low. Evidence of the interdependence between these two life-histories is widespread. Genetics studies confirm that anadromous and resident individuals commonly interbreed, and otolith microchemistry and controlled breeding experiments have found that both life-history types produce offspring of the alternate type. Accounting for the interactions between codependent populations of anadromous and resident *O. mykiss* is critical to understanding why steelhead are often sustained at low numbers alongside abundant resident trout. Using a unique, long-term dataset we developed a stochastic life-cycle model that incorporated interactions between anadromous and resident *O. mykiss* to explore the effect of resident rainbow trout populations on abundance of sympatric steelhead in the Upper Yakima Basin. Recruitment between age classes residing in freshwater showed strong density dependence. Rates of interbreeding between types, and the proportion of offspring that became resident or anadromous from each parental cross were estimated from experiments conducted in the Yakima and Grand Ronde Basins. The relative abundances of steelhead and rainbow trout predicted by the model were similar to estimates from field studies. Furthermore, the model predicted that a significant portion of the low, yet stable number of adult steelhead returning to the Upper Yakima River would be derived from resident spawners. Thus, contributions from the resident trout population may strongly influence abundance of the anadromous life-history. We recommend further study of anadromous fish production from resident rainbow trout as a potentially important driver of steelhead persistence. Our results provide promising evidence that resident rainbow trout could be used by managers to bolster and sustain steelhead production in depressed populations.

## E. Emigration Behavior of Resident and Anadromous Juvenile *Oncorhynchus mykiss*: Exploring the Interaction among Genetics, Physiology and Habitat

Sean Hayes, NOAA Fisheries

We investigated the interaction among genetic origin, behavioral tendency to emigrate, habitat use, and $Na^+$,$K^+$-ATPase activity levels of subpopulations of resident and anadromous fish from the species *Oncorhynchus mykiss*. Genetic origin had a strong

impact on life history choice with resident fish being far less likely to emigrate downstream than anadromous fish. Non-migratory fish typically showed low $Na^+,K^+$-ATPase activity levels throughout the year. Migratory fish had elevated $Na^+,K^+$-ATPase levels in the spring with larger fish tending to migrate to the ocean in February and March, while smaller fish, which had lower $Na^+,K^+$-ATPase, tended to migrate downstream from April through June and recruit to estuarine rearing habitat for the summer. Many of these summer recruits were observed retreating upstream into the watershed during late fall and were eventually determined to compose the largest size class of smolts passing through the smolt trap the following spring. The results of this investigation indicate that combined genetic and physiological analyses increase resolution of the proportions of anadromous and resident forms in a population, yielding several management implications including the need to 1) consider the resident rainbow trout phenotype as a component of the Distinct Population Segment management unit, 2) preserve and restore impacted estuary habitat and 3) provide adequate flows to maintain connectivity between estuary and upper watershed habitats.

## F. Population Genomics of Coastal California Resident and Anadromous *Oncorhynchus mykiss* in Scott Creek, CA

Devon Pearse, NOAA Fisheries

In central California, variation in life history patterns in a key characteristic of steelhead biology. Anadromous forms occupy a range of habitats from large river systems to small coastal streams. Resident populations above barrier falls, whether natural or stocked, can add an additional dimension to the variation present within a single drainage, and both forms can co-exist, even within small streams. Genetic data from Scott Creek *O. mykiss* has shown that resident rainbow trout above Big Creek Falls are derived from the anadromous population present in Scott Creek and that above-barrier trout are moving over Big Creek Falls into the population below. With the large number of salmonid microsatellite markers available and the rapid development of linkage maps, the effects of natural selection on specific regions of the genome can be identified. Natural selection typically affects a specific locus, but regions of the genome linked to genes affected by natural selection can be identified by identifying marker loci with greater differentiation between populations than expected by purely neutral genomic processes. We are using genome-wide data to identify genes under differential selection in the above-barrier and anadromous populations, as well as to determine the extent of hybridization between resident and anadromous fish below the falls and to conduct parentage analyses. Identification of regions in the genome that are potential areas for selection will provide valuable information about the genetic basis of selection in novel habitats.

## G. Density-Dependent Reinforcing Mechanisms of Anadromy in Partially Migratory Salmonid Populations

Matt Sloat, Oregon State University

*Oncorhynchus mykiss* is one species in a suite of salmonids exhibiting partial migration, the phenomenon in which a portion of individuals within a population adopts a migratory (e.g., anadromous) life history. While salmonids are one of the most studied groups of fish in the world, the proximate mechanisms underlying their life history expression are not well understood. Recent research with brook charr (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) highlight the importance of bioenergetic differences among individuals for the expression of alternate life histories. These differences manifest themselves as variation in relative allocation of energy to various metabolic pathways and may also have consequences for fish behavior and habitat use. Until recently comparable research had not been conducted for *O. mykiss* to determine if physiological characteristics correlate with life history expression. Here we present preliminary physiological comparisons of anadromous and resident *O. mykiss* from the Deschutes River. We also review the literature for other species to identify trends in additional important physiological, morphological, and behavioral traits that may be correlated with anadromous and resident life histories. Examining differences in physiology, morphology, and behavior provides an avenue for understanding the trade-offs associated with adaptations to anadromous and resident life histories. This information can then be used in mechanistic models such as bioenergetics and individual-based models to predict the consequences of changes in stream discharge, water temperature, and other ecological variables for the distribution and abundance of anadromous and resident *O. mykiss*.

## H. Description and Prediction of Broad-scale Spatial Variability in Expression of Anadromy in Female *Oncorhynchus mykiss* in the John Day River, OR, USA

Jason Dunham, U.S. Geological Survey

Partial migration is a common migratory behavior where some individuals in a population migrate and others do not. Patterns of partial migration can vary dramatically, especially for species that inhabit a wide range of environments. I described and predicted spatial variation in marine migration (anadromy) of female *Oncorhynchus mykiss* (steelhead and rainbow trout) in the John Day River catchment basin, Oregon. This large catchment (20,500 km²), where *O. mykiss* is known to exhibit partial migration, encompasses a broad range of environmental conditions. I collected 149 juvenile *O. mykiss* across 72 sites and identified locations used by anadromous females by assigning maternal origin (anadromous versus non-anadromous) to each juvenile. These assignments used comparisons of strontium to calcium ratios in otolith primordial and freshwater growth regions to indicate maternal origin. Individuals within sites were more likely to have the same maternal origin than expected at random ($\chi^2$ test, $P < 0.001$). I used logistic regression to predict probability of anadromy among sites in relation to stream size (as indicated by mean annual runoff). Stream size and maternal origin for single fish collected from 69 sites were used to construct a predictive

model. I examined the ability of this model to predict new individuals at 47 of these sites (where a second fish was collected) using a variety of diagnostics, including kappa statistics and receiver operating characteristic curves. The model predicted anadromy in this second set of individuals with a moderate level of accuracy (e.g. 68% correctly predicted with a 0.5 classification threshold). Residuals from the model were not spatially autocorrelated, as indicated by Mantel tests. This result also suggested that remaining variability in the expression of anadromy was due to localized influences, as opposed to broad-scale gradients unrelated to stream size. The importance of stream size implies that occurrence of migratory females was related to environmental variability, but stream size is an indicator of many potential processes, and I was unable to identify a specific likely mechanism. However, I was able to demonstrate 1) that it is possible to predict the probability of anadromy across broad environmental gradients, and 2) the validity of a sampling approach that minimizes the need for sacrificial sampling of individuals. These results are important for the management of *O. mykiss* because anadromous individuals (steelhead) within the John Day River watershed are listed as threatened species, and it is difficult to discern steelhead from non-anadromous individuals (rainbow trout). My results provide managers with the first broad-scale description and prediction of location supporting anadromy, and provide a broad template that can guide future habitat restoration, monitoring, and research to better manage and understand the expression of anadromy in *O. mykiss*.

## I. Development of a Water Temperature Model to Predict Life-History Expression and Production of *Oncorhynchus mykiss* in the John Day River Basin, OR

Jeff Falke, NOAA Fisheries

Populations of steelhead trout, the anadromous form of *Oncorhynchus mykiss*, have declined precipitously in the past two decades, resulting in listing under the federal Endangered Species Act across a large portion of its range. Confounding recovery, considerable uncertainty exists with regard to the interaction between stable populations of the resident life-history form (i.e., rainbow trout) and threatened anadromous steelhead. In many locations the two forms are sympatric and one form may give rise to the other. Historically, the two forms have been managed separately, yet recent research shows that populations that exhibit high life-history diversity are both more productive and resilient to perturbation. The decision to migrate or stay in freshwater may be influenced by gender and be a flexible response to variable environmental conditions. Therefore, recovery of steelhead will require an increased knowledge of the physical and biological processes that influence expression of life history in *O. mykiss*. Water temperature is a key control on growth and survival of fishes and ultimately influences life-history expression. As such, an important first step is understanding the natural variation in thermal conditions across the broad spatial scales at which *O. mykiss* carries out its life-history. The focus of our current research is to develop a spatially explicit, continuous water temperature model for the John Day River basin in eastern Oregon, based upon an extensive database of water temperature observations collected there across 20 years. The model is parameterized using remotely sensed

land-surface temperatures, precipitation, runoff, and physical aspects such as stream size, catchment area and gradient. Ultimately this modeling will contribute to our goal of predicting life history expression and production of *O. mykiss* in the John Day and assist in developing an analytical framework that is useful for managers to evaluate conservation and management actions aimed at increasing juvenile steelhead production.

## V. Contributed Posters

Session Chair: Carol Coyle, Alaska Department of Fish & Game

### A. Calcein Mark Retention in Chinook Salmon and Steelhead Trout Fry in Artificial and Natural Rearing Environments

Cory Quesada and Megan Hill, Portland General Electric

Managers and researchers need a mark to distinguish between resident and anadromous life histories of juvenile *Oncorhynchus mykiss*. A mark to evaluate survival and growth of hatchery fish released into the stream is also needed. These questions are pertinent to the Deschutes River Basin, Oregon, where steelhead trout and *O. tshawytscha* (spring Chinook salmon) reintroduction is underway. Hatchery Chinook and steelhead fry were marked with calcein dye to determine its efficacy for identifying fish after release. Calcein is a dye that binds to the calcified structures of fish; the dye is visible in external structures such as fin rays when exposed to the proper wavelength of light. Fry were marked via osmotic induction by immersing each hatchery incubation tray in a salt bath, followed by a calcein bath. The effects of calcein treatment on growth and survival of marked fish, and mark retention over time were evaluated. Minimal differences in growth were observed between marked and unmarked Chinook salmon, and there was no difference in the length of marked and unmarked steelhead trout at the conclusion of the study. Calcein marking had no effect on survival during the 8 week experiment. The calcein mark rapidly lost its intensity over time. Chinook fry were monitored in stream habitat after release where mark retention fell to 20% and 0% at 6 and 8 months respectively. Steelhead fry were marked and reared under 3 light treatments to directly evaluate if UV light exposure affected calcein retention. After 28 d light exposed fry had no visible calcein marks whereas fry held in covered tanks had 100% mark retention. Currently calcein is not a viable option for marking fry in stream environments due to mark degradation with UV light exposure.

### B. Focus on Alaska Fisheries: Using Underwater Video Technology to Monitor Fish Runs

Ken Gates, U.S. Fish and Wildlife Service

Underwater video systems have become an important tool allowing resource managers to do more with less. Currently, underwater video systems are being used across many U.S. Fish and Wildlife Service Programs including Fisheries Assessment and Monitoring, Subsistence Management, and Refuges. The Kenai Fish and Wildlife Field Office began experimenting with video technology to develop a cost effective method to accurately monitor salmon returns in Alaska. Since then, we have expanded, improved, and incorporated video technology into several of our fish weir projects to remotely monitor salmon and steelhead. Underwater lights and a camera are mounted in a sealed video box filled with clear water. Images of fish are captured as they are channeled through a narrow passage chute mounted to the front of the video box. This capability has allowed us to infiltrate turbid water during periods of spring run-off to

monitor previously undocumented steelhead populations in several streams throughout south-central Alaska. The major biological benefits of underwater video monitoring include more accurate escapement estimates, unobstructed fish passage, and the ability to operate during high flows and turbid water conditions. Major operational benefits include significant long-term cost savings, the ability to operate more projects with less people, ease of integration with various research projects, and a reduction in our carbon footprint.

## C. Fish Behavior Impedes Estimation of Adult Steelhead Using a DIDSON in Peterson Creek, Alaska

Carol Coyle, Alaska Department of Fish and Game

There is a need for a reliable counting method as an alternative to a standard weir to assess steelhead escapement in remote streams in Southeast Alaska. The Alaska Department of Fish and Game tested a DIDSON in Peterson Creek to count a small stock (N ~ 200) of spring steelhead from April 20 – June 5, 2009. The DIDSON was operated in a 8 m wide section of stream and provided near video-quality images of steelhead. Detection of these images allowed enumeration, direction and time of passage, size and midstream range of each fish. Analysis of the images collected continuously during the field season revealed that 747 steelhead immigrated past the DIDSON while 445 emigrated. Daily upstream/ downstream behavior of the steelhead in this low-gradient system appears to have artificially inflated the count of steelhead at the DIDSON site. To account for this behavior, we used a Decision Support Tool (Pipal et al., *in prep*.) that matched opposite moving steelhead within an hour passage of each other scored by elapsed time, length, and group size to determine which fish were likely the same. Employing this tool, the revised number of steelhead was 542 immigrants and 240 emigrants, a still much higher abundance than thought to be in the stream. The DIDSON also appeared to undercount kelts, a likely effect of aiming and higher than anticipated water levels. While, the DIDSON shows promise for counting iteroparus steelhead in small streams, more rigorous protocols must be developed to account for the daily migratory behavior of steelhead, aiming to incorporate both immigrants and kelts, as well as validation methods.

## D. Summer Steelhead Redd Surveys Above a Weir: Deer Creek, Oregon

Jim Ruzycki et al., Oregon Department of Fish and Wildlife

The goal of this monitoring is to establish a relationship between spawners and visual counts of summer steelhead redds in a tributary with a known spawner escapement. An adult weir and trap at our Big Canyon acclimation facility provides the spawner escapement because all unmarked adults are counted and then passed above the trap to spawn naturally in Deer Creek. Since 2002, annual spawning ground surveys have been conducted above the weir to observe and estimate the number of redds and has resulted in a strong correlation between redds and adults ($R \approx 0.85$) over the past 8 years. This relationship was further improved ($r^2 = 0.98$) when an index of redd visibility

was incorporated using multiple regression. Redd visibility was evaluated by revisiting and ranking previously identified redds on a scale from 1–5. We subsequently used redd and adult counts to estimate an annual fish/redd ratio for Deer Creek which has varied from 1.17–4.07 since 2002. The strength of this relationship has also given us confidence in applying it to our regional steelhead surveys that estimate redd densities at the watershed scale. By applying the annual fish/redd constant, we estimate steelhead spawner escapement in the John Day and Upper Grande Ronde River watersheds where we currently conduct annual spawning ground surveys for steelhead status and trend.

## E. Steelhead Smolt Emigration: The First Year of Acoustic Monitoring Through the Lower American River and Sacramento San-Joaquin Delta system

Erin Collins and Robert Titus, California Department of Fish and Game

Little is known about smolt emigration, including timing and survival, of wild juvenile steelhead on the lower American River. Work to date by the California Department of Fish and Game suggests that most wild steelhead in the lower American River smolt at age 1. However, very little is known about what months of the year these fish smolt, how far they travel, how long the migration takes, and when and where the fish experience relatively high mortality. More specific questions include: Do some smolts go to the ocean while others stay in the Sacramento-San Joaquin Delta (Delta) system? Do some never leave and become resident fish, or “rainbow trout?” This information is very important for our basic understanding of steelhead ecology and has been unattainable to date through standard river sampling methods such as rotary screw traps. We initiated a monitoring study in early 2008 to address these questions using acoustic tag technology. Our study takes advantage of a network of hydrophones already in place on the Sacramento River and throughout the Delta and San Francisco Bay. In addition, we have added four hydrophones over the course of the lower American River. Our target was to tag 100 smolts with V9-1L Vemco tags between January and April 2008, but we only succeeded in tagging 13 steelhead smolts. As of May 2008, eight smolts have moved downstream past our lowermost hydrophone, three of which were detected at the Golden Gate Bridge. Of the remaining five tags, two have not been detected on any of the hydrophones, and three have not moved from the area in which they were first tagged and released. We will resume tagging steelhead pre-smolts in September 2008 to provide opportunity to monitor for a potential late fall-early winter emigration of fast growing young-of-year steelhead from the lower American River.

## F. Seasonality and Sizes of Salmonid Smolts (*Oncorhynchus spp.*) in Fall Creek, Oregon

Camille Leblanc et al., Oregon State University

Salmonids are at risk throughout Oregon including some populations that are federally listed as threatened or endangered. This poster presents the results of trapping for smolts in Fall Creek (a tributary of the Alsea River), Oregon, from April to June 2009.

This was part of a project monitoring the downstream behavior and survival of steelhead in the Alsea basin. We documented: 1) the timing of migration, 2) the number of fish caught and their body lengths, 3) the trap efficiency, 4) and the estimated number of migrants for each species: steelhead trout (*Oncorhynchus mykiss*), cutthroat trout (*Oncorhynchus clarkii*) and coho salmon (*Oncorhynchus kisutsh*). The peak of steelhead smolt migration was mid - April whereas both coho salmon and cutthroat had a peak of smolt migration in early May. Early May also corresponded to high water flow in Fall Creek. The three species also differed in the relationship of body length to time of migration. There was no size trend over time in coho smolts, earlier migrants were the biggest in steelhead trout and the bigger smolts were at the peak of migration for cutthroat trout. This poster is a detailed chronology of juvenile salmonid movements as a baseline for further work on salmonid smolts in the Alsea basin.

## G. John Day River Steelhead: Lost in the Columbia

Jeff Neal and Jim Ruzycki, Oregon Department of Fish and Wildlife

PIT detections in the Columbia River migration corridor suggest that wild John Day steelhead return to Bonneville Dam in more than sufficient numbers. However, less than half of them get detected returning to the John Day. Over half of our steelhead miss the mouth of the John Day and are detected going over McNary Dam, never to be heard from again. These fish rarely show up at PIT detectors on other spawning tributaries. They are lost in the Columbia. We have no idea why this occurs and plan to solicit information from Conference attendees on where we should begin to look for answers.

## VI. Reproductive Success and Related Genetic Studies of Steelhead

Session Chair: Cameron Sharpe, Washington Department of Fish & Wildlife

### A. Inbreeding and Inbreeding Depression in Hatchery Steelhead

Todd Seamons, University of Washington

Several negative genetic effects of captive propagation have been identified including inbreeding in the captive population. These populations may appear demographically healthy, but management practices can result in inadvertent reductions in genetic variation underlying phenotypes decreasing their fitness. Here, as part of a long term research program studying wild and hatchery steelhead, we evaluated the extent and effects of inbreeding in the hatchery population. We calculated delta F, the probability that both alleles at a locus are identical by descent, using our four generation pedigree inferred from microsatellite data. Multiple levels of inbreeding were detected in the hatchery population, but the overall level of inbreeding was no more than expected given the per generation effective population size. We are currently examining the data to determine the effects of inbreeding on various fitness-related traits (inbreeding depression).

### B. Reproductive Success of Steelhead (*Oncorhynchus mykiss*) in Little Sheep Creek: As Time Goes By…

Ewann Berntson, NOAA Fisheries

Hatchery supplementation programs are designed to boost natural production; however, it can be difficult to evaluate the success of these programs. This study is an on-going investigation of relative reproductive success of steelhead spawning in nature, based on pedigrees constructed for hatchery-reared and natural steelhead. We genotyped adult steelhead that returned to the weir and were released upstream to spawn naturally on Little Sheep Creek. We also typed adult rainbow trout in the system, and determined the parentage of sampled progeny including parr, smolts, and returning adults. Initial results for parr indicated the relative reproductive success of hatchery fish was significantly less than that of their natural counterparts (30-60%). Adult-to-adult returns showed results similar to those found with juveniles, suggesting the measured lower relative reproductive success of hatchery-reared *O. mykiss* is the result of interactions before the parr stage (i.e., differences in mating behavior, or survival of resulting embryonic stages). These supplementation hatchery fish are genetically similar to wild, yet they exhibit a substantial decrease in fitness based on parentage analysis. Differential survival and behavior of offspring and/or spawning adults may all contribute to diminished fitness in hatchery-reared salmon. Despite complications presented by these potentially confounding factors, the analysis of these adult returns closes the life history loop in this system, and takes us a step closer to understanding why natural origin *O. mykiss* typically out-perform their hatchery counterparts.

## C. Natural Reproductive Success of First-Generation Hatchery Steelhead Spawning in the Kalama River, Washington

Cameron Sharpe, Patrick Hulett, Chris Wagemann and Maureen Small,
Washington Department of Fish and Wildlife

Naturally-produced ("wild") summer-run steelhead were used as broodstock in a new hatchery program at Kalama Falls Hatchery for three consecutive years (1999, 2000 & 2001). Adult offspring from the hatchery (H) releases that returned to spawn in 2003, 2004 and 2005 were passed above a barrier falls to spawn with an approximately equal number of phenotypically similar wild (W) fish. Adult offspring returning in 2006, 2007and 2008 from W×W, H×W, and H×H crosses were identified and enumerated using microsatellite DNA pedigree analysis. Preliminary results indicated no statistically significant difference in reproductive success between the wild and first-generation hatchery fish that spawned in 2003 (most adults from this brood have returned) and 2004 (partial returns). We did detect anadromous offspring where one of the parents was a resident trout. We did not detect any anadromous fish where one or both of the parents were residual (non-migrant) hatchery fish. The final analysis will be complete when samples from adults that returned in 2009 are processed (samples are being analyzed now).

## D. Where Are All of the Missing Parents? Grandparentage Analysis Identifies Reproductively Successful Residualized Hatchery Fish

Mark Christie, Melanie L. Marine and Michael S. Blouin, Oregon State University

Several studies with complete sampling of anadromous fish report that a substantial number of individuals cannot be assigned to a parent. These missing parents are inferred to be resident individuals or sampled individuals with genotyping errors. Here, we examine a 15 year data set of 12,725 winter-run steelhead (*Oncorhynchus mykiss*), where all anadromous fish were genotyped at 8 polymorphic microsatellite loci. We used conservative parentage methods to identify steelhead with one true parent and one missing parent. Out of the candidate steelhead, 23% were identified as missing a father and 5% were identified as missing a mother. We documented more successful matings between wild anadromous females and resident males than between hatchery anadromous females and resident males. We developed novel grandparentage methods to determine whether the missing parents were hatchery residualized fish (i.e., fish that remain in natal streams). The grandparentage methods determine the expected number of false grandparent-grandoffspring pairs for data sets with or without a known parent or grandparental breeding matrix. Both simulated and direct validation demonstrated these methods to have low bias and high precision. Using the grandparentage methods, we determined that between 6.3% and 14.2% of missing parents were hatchery residualized steelhead. The median age at spawning for hatchery residualized males was 1 year, while the median age at spawning for hatchery residualized females was 5 years. We conclude that hatchery fish can become reproductively successful residents and that these results should guide future conservation and management efforts.

## E. Stocking of Captive-Bred Fish Can Cause Long-Term Population Decline and Gene Pool Replacement: Predictions from a Population Dynamics Model

Hitoshi Araki, Eawag, Swiss Federal Institute of Aquatic Science and Technology

Releasing captive-bred fish into natural environments (stocking) is common in worldwide fisheries and is becoming increasingly popular for the conservation of declining populations. Although stocking is believed to have a positive effect on fish abundance over the short term, little is known about long-term consequences of recurrent stocking and its influence on natural populations. In this study, we theoretically address the long-term effects of recurrent stocking. We developed a population dynamics model that considers hybridization between wild and captive-bred fish and evaluate the demographic and genetic consequences of stocking simultaneously. The model showed that recurrent stocking does not contribute to stock enhancement without a replacement of the wild genotype by the captive-bred genotype. The model further predicted that stocking at an intermediate level causes a decline, rather than recovery, of population size over the long term. These results suggest that there is no room for compromise between population size recovery and conservation of the local gene pool. Our results are consistent with the fact that there is scant evidence that stocking has boosted the long-term productivity of natural populations, although caution is needed when applying the model predictions to a specific system or species. According to this model, the population decline due to recurrent stocking is attributed to the fitness disadvantage of captive-bred fish and severe density-dependent competition at recruitment stage. Therefore, minimizing genetic changes in captivity and increasing the carrying capacity of a habitat will be the effective means of mitigating the negative impacts of recurrent stocking.

## F. Genetic Impacts of Hatchery Stocks on Steelhead in Lower Cowlitz River Tributaries

Anne Marshall, Washington Department of Fish and Wildlife

Naturally spawning winter-run steelhead in lower Cowlitz River tributaries are included in the ESA-listed Lower Columbia River Distinct Population Segment (DPS), and designated as a distinct historical population. Among existing populations within the DPS there is a high degree of uncertainty regarding the impacts of hatchery stocks on genetic diversity and viability. Three hatchery steelhead stocks, summer-run, early-winter-run, and late-winter-run, are produced at the Cowlitz Trout Hatchery upstream of the lower Cowlitz tributaries. The late-winter-run hatchery stock is the only local-origin stock, and the early-winter-run stock was derived from a Puget Sound stock. We sampled 77 natural-origin and 8 marked hatchery steelhead on spawning grounds in lower Cowlitz tributaries from March through May in 2008 and 2009. We characterized these fish at 15 microsatellite DNA loci and compared them genetically to the three Cowlitz Hatchery stocks. All three hatchery stocks were well-differentiated from each other. As a group, lower Cowlitz natural-origin spawners were genetically distinct from the hatchery stocks but had substantial proportions of ancestry or introgression from the

non-native early-winter-run and summer-run stocks. We estimated that five of the marked hatchery fish were from the early-winter-run stock, and these fish were on spawning grounds in spring. In comparisons with populations in other Cowlitz or lower Columbia drainages, lower Cowlitz natural-origin steelhead were most similar genetically to natural-origin steelhead in the Coweeman River, a nearby Cowlitz sub-basin, and to steelhead in the Elochoman River, which are not in the Lower Columbia River DPS. Both these rivers receive releases of a early-winter-run hatchery stock that shares the same Puget Sound origin as the Cowlitz Hatchery early-winter stock. Lower Cowlitz steelhead were distinct from wild steelhead in the Toutle River, another nearby Cowlitz sub-basin. Our results demonstrated that native gene pool ancestry remained high in lower Cowlitz steelhead despite large and long-term upstream releases of hatchery stocks. It also appeared that introgression from hatchery stocks is a significant issue in recovery planning for this ESA-listed population.

## G. Genetics Investigations of Steelhead in the Central Valley of California

Devon Pearse and John Carlos Garza, NOAA Fisheries

Steelhead/rainbow trout (*Oncorhynchus mykiss*) are found in all of the major drainages of the Central Valley, which includes rivers and streams that drain into both the Sacramento and San Joaquin sub-basins. Most of the tributary rivers in this area have dams or other impoundments and many of the resulting reservoirs have been stocked with hatchery rainbow trout. Genotype data was collected from 18 highly variable microsatellite molecular markers in more than 1600 fish sampled by California Department of Fish and Game biologists, as well as a sample of adult steelhead from Battle Creek sampled by the US Fish and Wildlife Service. These included 17 initial "populations" sampled from the Kings, Tuolumne, Stanislaus, Calaveras, American, Yuba, Feather, Butte, Deer, Battle and McCloud River sub-basins. Analysis of these data examined population structure within the region, relationships between populations above and below barriers to anadromy, and population genetic diversity. Additional analyses were conducted with data from the same microsatellite markers in rainbow trout hatchery stocks and steelhead from coastal California populations to determine whether specific fish are descended from hatchery strains used in local stocking efforts, as well as to evaluate the relationships of Central Valley populations to coastal steelhead.

In general, although population genetic structure was found, all naturally-spawned populations within the Central Valley basin were closely related, regardless of whether they were sampled above or below a known barrier to anadromy. This is likely due to some combination of pre- impoundment historic shared ancestry, downstream migration and, possibly, limited anthropogenic upstream fish movement. However, lower genetic diversity in above-barrier populations indicates a lack of substantial genetic input upstream and highlights lower effective population sizes for above-barrier populations. In contrast to coastal steelhead, we did not find close relationships between populations above and below barriers within the same sub-basin. Instead, above-barrier populations clustered with one another and below-barrier populations clustered with one another in

all tree analyses. Analysis using data from coastal steelhead populations found that the above-barrier populations enter the California-wide trees next to the San Francisco Bay populations, whereas the below-barrier populations are more closely allied with populations in northern California, specifically the genetic groups that include the Eel and Klamath Rivers. Since Eel River origin broodstock were used for many years at Nimbus Hatchery on the American River, it is likely that Eel River genes persist there and have spread to other basins by migration, and that this is responsible for the clustering of below-barrier and northern California populations. This, in combination with the observation of large numbers of hatchery rainbow trout entering Nimbus Hatchery and potentially spawning as steelhead, suggests that the below-barrier populations in this region have been widely introgressed by hatchery fish from out of basin broodstock sources. The consistent clustering of the above-barrier populations with one another, and their position in the California-wide trees, indicate that they are likely to more accurately represent the ancestral population genetic structure of steelhead in the Central Valley.

## VII. Adult Steelhead Abundance Monitoring

Session Chair: Dan Rawding, Washington Department of Fish and Wildlife

### A. A PIT Tag Approach to Estimate Multiple Steelhead Populations at Bonneville Dam

Jeff Fryer, Columbia River Inter-Tribal Fish Commission

CRITFC has been sampling salmonids to estimate age, length at age, and stock composition at the Bonneville Dam since 1985, though steelhead only since 2004. In recent years, genetics samples have also been collected. Since 2006 we have also been PIT tagging fish sampled, and in 2009 using Columbia Basin Accords funding, PIT tagged 2399 steelhead between April 21 and October 21, one third with 20.0 mm tags and the remainder with standard 12.5 mm tags and tracked them upstream. Since these steelhead are still in the system, results are preliminary. We observed little difference between tag type performance so we plan to discontinue 20.0 mm tags. Over 99% of passing PIT tagged steelhead were detected at mainstem dams. Thus far, the estimated percentage of steelhead reaching McNary Dam is 66.6%, with 45.3% reaching Lower Granite, 9.6% reaching Priest Rapids, and 6.3% reaching Wells Dam. The percentage reaching the Snake River steadily increased over the sampling period at Bonneville Dam from less than 20% to over 70%. The above Priest Rapids component peaked at just under 20% in late August. This project was hampered by sampling restrictions imposed by the Fish Passage Operations and Maintenance (FPOM) committee that greatly reduced sample sizes during peak run periods. During three weeks in August, only 376 steelhead (15.5% of our sample) represented over 271,000 steelhead (44.9% of the run). During one week 3.6% of the run migrated, no sampling was allowed. Analysis of Chinook salmon previously PIT tagged as juveniles indicate that the trap configuration imposed by FPOM in 2009 is heavily biased towards jacks. There is insufficient data to indicate what other Chinook biases may be present, or if there are trap biases affecting steelhead. However, these trap biases, as well as low sample sizes during peak migration periods suggest results from this study should be used with caution. CRITFC, TAC, and PSC are urging changes in trap configuration and operations in 2010.

### B. Estimating the Size of Steelhead Runs by Tagging Juveniles and Monitoring Migrants

David Boughton, NOAA Fisheries

The number of individuals in a spawning run of anadromous fish can be estimated by PIT-tagging juveniles during the fish's freshwater phase, and subsequently monitoring migrants using in-stream tag readers. The method may enable monitoring of steelhead trout (*Oncorhynchus mykiss*) in systems where other methods are intractable. I developed a hierarchical capture-resighting model and applied it to simulated data to develop a relation between the number of marked juveniles and the precision of

run-size estimates. Precision is primarily controlled by the number of tagged spawners that ultimately return and get detected, with only 30 to 90 tagged spawners required to obtain relatively precise estimates of run size. For typical marine survival rates, 0.0033 – 0.033, this translates to a tagging effort between 3,400 and 45,000 juvenile fish per cohort. Estimates are robust to imperfect detection of tagged fish if at least two in-stream readers independently scan for tags. Reach-sampling allows estimates of run size in large stream systems. In my simulations, the number of reaches could be as low as 30-40 under scenarios of high marine survival. Computer code is provided for the estimator using the freely available statistical software R.

## C. Adult steelhead Abundance Estimates Based on PIT Tag Arrays in Idaho

Rick Orme, Nez Perce Tribe

Currently there is limited quantitative information on adult Snake River steelhead populations (*Oncorhynchus mykiss*) in tributary streams upstream of Lower Granite Dam. Current methodologies use steelhead adult abundance for the aggregate of populations determined from fish ladder counts at Lower Granite Dam. Contemporary methods, (e.g. redd counts, weirs) are limited throughout most the upper Snake River drainage due to geographic inaccessibility and high stream flows during the spawning period, additional techniques need to be developed to estimate population abundance. The Integrated Status and Effectiveness Monitoring Project (ISEMP) recently initiated a pilot project to determine whether innovative methods can be employed to increase the accuracy and precision of juvenile and adult abundance by age for summer Chinook salmon at the subpopulation, population, and major population group (MPG) scales and for steelhead at the subpopulation and population scales. As part of this pilot project, wild/natural adult escapement estimates will be generated through adult sampling and passive integrated transponders (PIT) placed in adult fish at Lower Granite Dam in conjunction with PIT tag detections from flat panel pass-over PIT tag arrays currently operating within the South Fork Salmon River and the Lemhi River, Idaho. This methodology requires that adults are representatively PIT tagged at Lower Granite Dam and that enough PIT tags are applied to get sufficient stream detections for calculation of precise escapement estimates. The precision of the adult escapement estimate is dependent on both the variance estimate of the total population size at Lower Granite Dam and the variance of the estimated number of PIT tags at the arrays. Simulation modeling incorporating total run size, PIT tagging rate, and array detection efficiencies suggest that the coefficient of variation (CV) of stream specific escapement estimates will be acceptable for most management applications.

## D. Estimating Viable Salmonid Population Parameters for Snake River Steelhead Using Genetic Stock Identification of Adult Mixtures at Lower Granite Dam

Tim Copeland, Idaho Department of Fish and Game

We identified the stock composition of adult wild steelhead (*Oncorhynchus mykiss*) passing Lower Granite Dam on the Snake River by sex, length, age, and run-timing. A total of 1,087 samples collected at Lower Granite Dam August 24 - November 25, 2008 were genotyped with 13 standardized steelhead microsatellite loci and a new modified Y-specific genetic assay that differentiates sex in O. *mykiss*. A genetic baseline of 66 populations was utilized to complete genetic stock identification (GSI) of unknown-origin samples from Lower Granite Dam. Large differences in reporting group (stock) contributions were observed for the run as a whole, with the Snake/Lower Clearwater reporting group having the largest single contribution (36.1%). Other large contributors included the Upper Clearwater reporting group (15.4%) and the Lower Salmon reporting group (13.9%). Smaller contributions came from the other 6 reporting groups: Imnaha (9.5%), Upper Salmon (9.2%), South Fork Clearwater (7.6%), Middle Fork Salmon (5.1%), South Fork Salmon (2.7%), and Elk Creek (0.5%). Significant differences in reporting group contributions were observed when samples were grouped by length, age, and run-timing. Of the samples analyzed, 339 were identified as males (34.3%) and 650 were identified as females (65.7%). There were no significant differences in reporting group contributions between males and females. This is the first study to use genetic stock identification mixture analyses to estimate individual stock contribution of Snake River steelhead over Lower Granite Dam. These results demonstrate that this approach should greatly assist managers with the task of assessing the viability of the Snake River steelhead ESU by providing information to estimate Viable Salmonid Population parameters involving abundance, population productivity, spatial structure and diversity.

## E. Calibration of Redd-Based Methodologies in Coastal Oregon

Erik Brown, Oregon Department of Fish and Wildlife

Monitoring of adult winter steelhead (*Oncorhynchus mykiss*) in coastal Oregon streams has been based on a GRTS (EMAP) site selection process in concert with redd-based survey methodology since 2003. These methods were developed during a previous but unpublished calibration study. Starting in 1998, we began evaluating the use of spawning ground redd counts as a measure of adult abundance. We comprehensively surveyed spawning areas above adult counting stations for steelhead redds and developed relationships between adult passage counts and redd counts (N= 10, R2 = 0.98, p = 0.001). In return years 1999-2000, 2000-2001, 2001-2002 we tested the predictive capability of our methodology in Smith River Basin. A moderate sized coastal basin with 261 stream miles. We developed two independent estimates of adult abundance. One using mark-recapture and the other using redd counts in randomly selected EMAP sample sites. In all years both methods yielded similar estimates. We developed two independent estimates of hatchery stray rates. One based on visual

determination on the spawning grounds and the other of fish handled at the falls. We found no significant difference p=(0.05) of the two estimates in any of the years sampled. Starting in 2002-2003 return year, we implemented the EMAP sampling methodology coast-wide.

## F. An Approach to Estimate the Precision of Redd Based Steelhead Escapement Estimates

Bryce Glaser, Washington Department of Fish and Wildlife

Redd based escapement estimates are commonly used by the Washington Department of Fish and Wildlife (WDFW) to estimate steelhead abundance. While this method is often inexpensive, cost-effective and easy to implement, resulting escapement estimates can be relatively imprecise. Redd counts are multiplied by a female per redd estimate and a ratio of adults to females, or simply by a fish per redd estimate to develop an estimated number of spawners. Sources of uncertainty are: female (or fish) per redd estimates, sex ratios, and the sampling design. Calibrated surveys are used to develop estimates of females (or fish) per redd, by conducting redd surveys in conjunction with a weir or mark-recapture program that develops estimates of escapement for a given population. Partially calibrated surveys are conducted where estimates of females (or fish) per redd from calibrated surveys are used in a different basin to expand redd counts. Sex ratio data is collected at weirs or fish traps, preferably where a census (or near census) count is possible. Redd survey sampling designs typically include census counts, index/supplemental counts, and generalized random tessellation stratified (GRTS) sampling. The largest source of variation in redd based steelhead escapement estimates is from estimates of females per redd. The smallest source is from sex ratio data. The level of variance from sampling designs depends on the level of effort. Using standard WDFW redd count expansion methodology, the overall steelhead escapement coefficient of variation (CV) ranged from 20% for a census count design to ~25% for GRTS and index/supplemental count designs. If redd surveys are to be used to estimate escapement, WDFW needs additional calibrated studies to better estimate females or fish per redd. If redd based escapement estimates are not able to meet recommended ESA, research, and/or management precision goals for key populations, then alternate escapement methods should be considered.

## G. Escapement Methods and the Representativeness of ODFW Life-cycle Monitoring Sites

Erik Suring, Oregon Department of Fish and Wildlife

The Life-Cycle Monitoring (LCM) Project of the Oregon Department of Fish and Wildlife has operated adult and juvenile traps on the Oregon Coast since 1998, monitoring coho and Chinook salmon, and steelhead and cutthroat trout. Sites were non-randomly selected for their ability to trap adult salmonids; however, habitat metrics in trapping basins have similar distributions to coast-wide estimates. Coho salmon returns at LCM

sites are highly correlated between sites and to coast-wide spawner surveys. Steelhead returns, however, are not correlated between LCM sites nor is there a relationship to coast-wide redd surveys. These results suggest that the complex life history of steelhead and geographic variation in survival increase the uncertainty of extrapolating results from small basins to larger scales compared to species like coho salmon. The LCM Project has also begun aging steelhead smolts and spawners to estimate marine and freshwater survival. Preliminary results indicate there are different freshwater age structures at different sites.

## H. Potential Utility of Juvenile Steelhead Abundance as a Surrogate for Adult Winter Steelhead Escapement

Ron Constable, Oregon Department of Fish and Wildlife

If trends in juvenile steelhead abundance showed a strong relationship with adult winter steelhead escapement the prospect of limiting sampling to one less life cycle phase could create monitoring efficiencies. Data from ODFW's Smith River Steelhead and Coho Monitoring Verification Study and from ODFW's Western Oregon Rearing Project (WORP) and Oregon Adult Salmonid Inventory and Sampling Project (OASIS) suggest little relationship between juvenile steelhead and the adults that produced them. Sampling juvenile steelhead by removal estimates and visual counts, the two primary juvenile sampling methods used in Western Oregon, pose many difficulties especially when the summer rearing population is small or has a patchy distribution. Juvenile steelhead may also have a naturally weak correlation with adults as the population is comprised of multiple cohorts and they are subjected to multiple ecological bottlenecks.

## I. Estimating Adult Steelhead Abundance in a High-Sediment Load Stream: Bridge Creek, Oregon

Ian Tattam, Oregon State University

Bridge Creek is a 710 $km^2$ basin which drains into the Lower Mainstem John Day River 218 km upstream from the Columbia. Bridge Creek flows through a highly erosive landscape, dominated by loess-type soils which remain in suspension once entrained in surface water. As a result, the creek is often turbid during the spring steelhead spawning period, making visual estimates of abundance such as redd counts difficult. During spring 2009, we employed a flexible picket weir and two-way trap to estimate the abundance of adult steelhead and occurrence of stray hatchery steelhead in Bridge Creek. We used Passive Integrated Transponder tags and caudal fin punches to facilitate a mark-recapture estimate of escapement. We estimated that 449 steelhead (95% Confidence Interval: 344 to 625) escaped into Bridge Creek. Nineteen percent of the steelhead captured at the trap were adipose-clipped hatchery strays originating from outside the John Day River basin. We will discuss the success of our trapping and marking methods, and compare our mark-recapture escapement estimate with a redd-count based escapement estimate.

## J. Adult Steelhead Monitoring Challenges in Cedar Creek, Washington

Josua Holowatz, Washington Department of Fish and Wildlife

Cedar Creek, a Lewis River tributary, has been part of the statewide fish in/out monitoring program since 1998. It is a low gradient stream that generally produces between 30-65,000 coho salmon smolts and greater than 1,000 adults annually but only 2-4,000 steelhead smolts and less than 300 adults annually. Because of large sample sizes and high trap efficiencies, juvenile outmigrant estimates for coho salmon, steelhead, and cutthroat have been precise, with a coefficient of variation (CV) ranging from 3 to 15%. Similar levels of precision have been achieved for estimates of adult Chinook salmon and with slightly less precise estimates for adult coho salmon. Steelhead estimates however, remain challenging due to low abundance and recapture rates, annual winter freshets, the lack of carcass recoveries, and the ability of adult steelhead to avoid adult traps. Several methods of mark-recapture have been utilized to estimate fishway use including releasing marked fish below the fishway (2003-06), a large hoop trap (2001-03) and resistance board weir with a trap (2007-present) installed 4 miles above the fishway, and adult seining (2007-present) and screw trap operation (2001-present) to collect kelts. Using recaptures from all sources, an annual Bayesian model (ABM) estimated that CV of adult steelhead abundance estimates ranged from 25% to over 200%. In nine, six, and four of the eleven years, the upper 95% CI of the population estimate exceeded 800, 1000, and 2000 fish, respectively. Using a hierarchical Bayesian model (HBM), which assumes that annual ladder use and adult abundance are part of common beta and normal probability distributions, yielded minor changes to the point estimates but improved the CV to 20% to 30%. Compared to the ABM, the HBM improved inferences for adult abundance when the annual data were sparse, and this approach should be considered in similar mark-recapture studies. We recommend additional effort to insure a minimum of 10 recaptures annually.

## K. A Bayesian Approach to Combine Multiple Sources of Escapement Data to Estimate Wind River Steelhead Abundance

Dan Rawding, Washington Department of Fish and Wildlife

The Wind River is a tributary to the Columbia River and is located 55 miles east of Vancouver, WA. This watershed supports a native run of ~ 500 summer steelhead. Since 1999, a trap located in the Shipherd Falls fishway (RiverMile 2) has been operated to tag summer steelhead in order to estimate the population abundance using a Petersen estimator. The recapture event has occurred in a fishway trap at Hemlock dam in lower Trout Creek, which was removed in 2009. Resight of tags also occurs through two independent snorkel surveys. Due to the removal of the recapture site at Hemlock dam, the motivation of this Bayesian analysis is to determine if mark-resight (snorkeling) is a robust alternative to mark-recapture (trapping). First, we present results from secondary experiment to test mark-recapture assumptions of closure, tagging effects, and equal catchability. The results suggest that less than 1% of the tagged fish emigrate from the river before spawning, the 21-day survival of tagged fish is over 99%, tag loss is time dependent and the probability of losing two tags from

tagging to prespawning is 3%, and there is equal mixing of tagged fish during the summer snorkel surveys. For the ten years, we generated 10 independent mark-recapture estimates, 10 snorkel estimates based on a method to estimate fish that successfully jump the falls, and 7 estimates based on a winter snorkel survey. Precision of individual estimates, as measured by the coefficient of variation (CV), generally ranged from 11% 22% with the jumper snorkel survey providing the most precise estimate in 8 of 10 years. Comparison of the estimates found no annual difference in 25 of 27 pairwise comparisons ($\alpha$ = 0.05). A model that combines the three independent estimates into a single likelihood resulted in more precise estimates (CV from 7% to 10%). This analysis suggests that mark-resight is a robust alternative to estimate the adult summer steelhead population in the Wind River.

## VIII. Movement in Time and Space

Session Chair: Charmane Ashbrook, Washington Department of Fish & Wildlife

### A. The View from 60,000 Feet: Macroevolution and Diversity in *Oncorhynchus mykiss*

Ken Currens, Northwest Indian Fisheries Commission

The first salmonid, *Eosalmo driftwoodensis*, occurred in British Columbia nearly 50 million years ago during the Age of Dinosaurs. Whether it is coincidence that its fossil remains were found in sediments of a stream named for its large woody debris (which we now associate with good steelhead streams), we may never know. In this talk, however, I trace the evolution and biogeography of Pacific salmonids as climates changed, mountains formed, and rivers changed course to extant patterns of diversity in *Oncorhynchus mykiss*. These patterns suggest the persistence and diversity of *O. mykiss* had more to do with the persistence of large river systems and the ability of the species to adapt multiple life-history strategies (such as anadromy, adfluvial migration, and residency) than it did with more localized effects of Pleistocene glaciation.

### B. Life histories of Central Valley steelhead: How does the American River stock fit in with the rest of the Sacramento Basin?

Erin Collins, California Department of Fish and Game

The American River consistently supports about 50% of steelhead angling effort in California's Central Valley. The present-day American River steelhead stock is of Eel River origin and consists of fish of both hatchery and natural origin. Naturally produced steelhead grow very quickly in the American River, smolt primarily as 1-year-olds, are strongly anadromous, and reach a large adult size like other central coastal California steelhead. While we have learned a great deal about American River steelhead over the past 20 years or so, important information gaps still exist that limit our ability to most effectively manage this important fishery resource and which may hamper recovery of the ESA-listed Central Valley Steelhead ESU. For example, little is known about the emigration timing of American River steelhead smolts. Recently developed information on emigration timing of hatchery and natural steelhead on the Sacramento River, though, provides a benchmark with which to both predict and compare emerging data on steelhead smolt emigration on the American. Other areas of uncertainty include water temperature effects on post-release survival in the sport fishery and in research involving invasive techniques, such as acoustic tagging. Pilot experiments to date and forthcoming investigations address these questions.

## C. Tracking steelhead migration from the Columbia River through the Pacific Ocean

Michelle Rub and Laurie Weitkamp, NOAA Fisheries

Steelhead are like other Pacific salmon in that they spend the much of their life in marine environments. However, very little is known about the marine ecology of steelhead: where they migrate in the ocean and how their migrations vary by season, by the age, or by the particular habitat types utilized during ocean residence. Having limited knowledge about the marine phase of Columbia River steelhead populations is particularly problematic because many of these stocks are protected under the U.S. Endangered Species Act of 1973. Because we lack fundamental information about steelhead migrational behavior in the ocean, we are greatly limited in our ability to understand the factors that influence their survival during this important period of their life cycle. Determining the pattern of migration and identifying the habitats that these stocks occupy is a critical first step in the process of gathering critical life history data on this species.

We propose to initiate a tagging program for Columbia River steelhead as a first step towards investigating their marine distributions. We will implant fish with both archival and acoustic tags to test whether or not we can obtain useful information about steelhead ocean migrations through a combination of sporadic albeit precise information on geo-position and a continuous but non-specific profile of the temperature and depth at which these animals travel. To do so, we will utilize fish that are being collected as bycatch by an ongoing study in the lower Columbia estuary. This study has caught between 150-1,000 juvenile steelhead each spring. Fish collected to date have originated from tributaries throughout the Columbia River basin and have been within the size range that is currently thought to be large enough to carry contemporary acoustic and archival tags. Due to the collection method (a 500-ft purse seine), collected fish have been in excellent condition with expected high post-release survival.

Archival tags (recording only temperature and depth) have the advantage that they are inexpensive, but the disadvantage that they must be retrieved in order to download the collected data. Acoustic tags, on the other hand, are considerably more expensive, but can be passively detected or “heard” by ocean receivers. There are currently three sets of ocean receivers with the potential to detect Vemco acoustic tags: 1) a towed array operated off the coasts of Oregon and Washington in August and September by the NOAA Southwest Fisheries Science Center (SWFSC); 2) the POST array located north along the continental shelf, and 3) an elephant seal 'array' consisting of 10-13 seals that will be 'deployed’ this winter/spring by the SWFSC. The third array is of particular interest because the seals are equipped with both Vemco receivers and geolocational devices so they have the potential to be utilized as roving acoustic arrays. Elephant seals are highly migratory and cover a large portion of the North Pacific in a given year, potentially overlapping the oceanic migrations of Columbia River steelhead.

## D. A comparison of life histories among selected Snake River steelhead populations

Brett Bowersox, Idaho Department of Fish and Game

Life history diversity is important to population resilience. The suite of life histories in a population influence its spatial structure, productivity, genetic diversity, and ultimately its abundance. Knowledge of these parameters is lacking for individual Snake River steelhead populations. Status assessments have been based on information from the Snake River aggregate or from coastal populations. We contrasted freshwater life histories present in selected populations within the Snake River steelhead ESU and considered implications for population productivity and management. We examined migration timing, age composition, and length at age of young steelhead leaving their natal streams in 2008 (Big Bear Creek, East Fork Potlatch River, Fish Creek, Crooked Fork, and Rapid River). In Fish Creek, 75% of emigrating juveniles left during the fall. In Big Bear Creek, East Fork Potlatch River, Rapid River, and Crooked Fork, the spring emigration comprised a much larger portion of the outmigration (87%, 65%, 61%, and 46%, respectively). Of the fish detected passing Lower Granite Dam, most spring emigrants were detected by mid-June; however, based on past data, fall emigrants will be detected 1-3 years later. Mean length at emigration out of natal stream differed among populations; average spring lengths ranged from 110.2 mm (East Fork Potlatch River) to 179.3 mm (Rapid River). In each population, 3-4 age classes emigrated. In East Fork Potlatch River, spring emigrants ranged 1-2 years in age; whereas they were 3-4 years in Crooked Fork. We attribute variation in juvenile life histories to habitat conditions within the different drainages (e.g., temperature regime and biological productivity). The distance from the ocean and diversity in elevation, hydrology, and geology in the landscapes Snake River steelhead inhabit make these populations diverse. Age structure of Snake River steelhead is more complex than assumed from previous status assessments. Management should account for these differences.

## E. What part of steelhead 'ocean mortality' can be explained by survival in lower rivers and estuaries

David Noakes, Oregon State University

Steelhead management and recovery plans are often based on population viability model projections. The data concerning survival by the various life history stages considered by these models can often have considerable error associated with them. We studied a means of improving upon estimates of ocean survival and identifying potential sources of mortality in lower rivers and estuaries of steelhead in the Oregon coastal distinct population segment (DPS). This DPS is recognized by NOAA- Fisheries as a species of concern and regulations are in place that protect native winter run steelhead from harvest. The overall goal of the study is to develop a means whereby survival to ocean entry can be estimated. Steelhead smolt survival to the ocean is currently estimated using data from smolt traps located well upstream of the estuary. Very little information on survival is available for this final phase of smolt migration between where the fish were last counted and the ocean. Mortality incurred in this zone

has previously been incorporated into survival models under the category of ocean mortality. Based on three years of data from the Nehalem River system and two years of data from the Alsea River system, our results show 1) wild steelhead smolts spend little time in the estuary, 2) typically only 40-50% of the wild steelhead smolts reaching the estuary actually enter the ocean, 3) most mortality occurs in the lower estuary, and 4) smolts tagged during the peak of the run appear to have higher survival rates. In addition, a multiple basin study design enabled us to investigate the possibility that mortality varies not only in a river system along a temporal scale but also between populations within the same DPS. We believe this research provides information that could strengthen the robustness of life cycle models used in recovery plans by providing missing data on mortality locations and rates in the riverine and estuarine portions of smolt migration. Ultimately, we will propose the design of a monitoring plan for estimating survival of migrants to the ocean within currently accepted errors.

## F. Hooking mortality and behavior of a Puget Sound population

Charmane Ashbrook, Washington Department of Fish and Wildlife

Recently Puget Sound wild steelhead populations were listed as threatened under the Endangered Species Act. Because wild and hatchery fish return at the same time, there is a need to identify the mortality impacts to wild fish that result from mark selective sport fisheries on hatchery fish. Despite many sport fishing mortality studies, the range of estimates is extensive, from 0% to 100%, and limitations to existing studies include that almost none use a control to estimate mortality. Finally, to our knowledge no studies have estimated wild steelhead hooking mortality in Puget Sound.

For two years, sport fishers captured wild winter steelhead in the Samish River, a Puget Sound tributary, using legal fishing gear (n=54). During the same time period, control fish were captured in fish traps (n=19). Radio telemetry tags were surgically inserted into both treatment and control fish and the migration and movement patterns were tracked using fixed and mobile receivers. The survival results indicate that although immediate and post-release survival to presumed spawning was 100%, there is a cost to being captured with sport gear following spawning. Although both treatment and control fish outmigrated, significantly fewer treatment fish outmigrated. Because it is difficult to verify that fish spawned successfully we used kelting behavior as a proxy for successful spawning, and this give an average mortality of 14.7% for sport captured fish. Ideally this estimate will be combined with encounter rate to estimate the total impact of sport fishing on wild Puget Sound steelhead.

To verify that the unmarked fish used in this study were wild, DNA analysis was performed. The results indicate that a fair percentage of fish were hatchery fish and included summer and winter run fish. No fish captured on sport gear were captured more than once during this project.

# IX. Contributed Papers

Session Chair: Hal Michael

## A. The Value of Repeat Spawning in Steelhead: Some Explorations with Age-Structured Population Models

Nick Gayeski, NOAA Fisheries

Female-only density-dependent age-structured population models were employed to investigate the value of repeat spawning to the persistence and growth rates of steelhead under deterministic and stochastic conditions. A total of five models were constructed with spawning at ages 4 and 5, two with no repeat spawning and three with repeat spawning. Density-dependence from post-emergent fry to age-1 (parr) was modeled as a type II functional response with common parameterization in all models. All models were initiated with a common total abundance level and age distribution and projected forward a minimum of 75 years.

Two sets of density independent parameters were employed. Set 1 (growth) conferred steady growth from less than 400 spawners to near 6000 within 50 years for both non-repeat (Model 1) and repeat (Model 2) spawning models. Set 2 (decline) resulted in the model without repeat spawners (Model 3) declining to an equilibrium just above 200 spawners within 50 years. Extinction was prevented by the inclusion of density-dependence. Two repeat spawning models under the decline parameterization (Model 4 and 5) that differed in the degree of repeat spawning were evaluated. Stochastic versions of each of the five models resulted from adding stochastic variability to the age two(smolt)-to-age three survival rate.

Repeat spawners were burdened by two costs: lower fecundity (egg number) at ages 4 and 5 than non-repeat spawners of the same age, and a lower probability of surviving from age 4 to age 5 than age 5 first-time spawners. In all models but Model 5 the proportions of each age and spawning life history type were set so as to equalize the expected lifetime number of offspring of each type at equilibrium. In Model 5, the proportion of immature age four fish that mature at age four was equal to that of the non-repeat models and the proportion of age four spawners that survive spawning and attempt to repeat was incremented until the decline was reversed. Model 5 thus represents the minimum degree to which repeat spawning would have to evolve in the non-repeat (Model 3) population in response to the decline in survival (relative to Model 1) in order to reverse the decline.

In all cases, the addition of repeat spawning results in fast growth from low abundance and larger equilibrium abundance and reverses the decline in the decline scenarios within two to four generations (10 - 20 years). In the stochastic versions, under decline conditions probabilities of decline to severe low abundance (<50 total spawners) within 200 years is considerably lower with repeat spawning than without.

## B. Kamchatka steelhead: Description of life history diversity and abundance

Peter Rand, Wild Salmon Center

Steelhead/rainbow trout ("mykizha") from Kamchatka (Russian Federation) exhibit population sizes and life-history diversity unequalled in the lower 48 United States, where habitat alteration and over-harvest have greatly reduced anadromous populations. The Salmonid Rivers Observatory Network (SaRON) is a collaboration among scientist from Moscow State University, Flathead Lake Biological Station and the Wild Salmon Center, formed in order to better understand the functioning of pristine salmon and steelhead ecosystems. As part of this work, we are examining the effects of physical complexity on life-history and genetic diversity in mykizha, along with the links between habitat complexity and juvenile densities, and we compare our results from Kamchatka to those from rivers in Alaska and British Columbia. There are little escapement data for mykizha in Kamchatka; however, we have recently generated a population estimate of adult steelhead in a tundra river system, the Utkholok River, using DIDSON sonar. The 2007 run was estimated to be ~10,800 individuals, a number far higher than what would be expected in a similar sized river system in the lower 48. This presentation is meant to stimulate thinking on the life history diversity and population dynamics of steelhead in a relatively pristine state.

## C. South Prairie Creek: What happens when you have a catastrophic overescapement of salmon?

Hal Michael

South Prairie Creek (SPC), a tributary of the Puyallup River system, offers an opportunity to evaluate the effect of large salmon escapements on steelhead. SPC is a clearwater stream rather than glacial, which allows for spawner surveys. The primary anadromous salmonids present are fall Chinook, pinks, and steelhead. Further, the three species and spawner surveyors are able to access almost the entire anadromous zone. Beginning in about 2001 the pink salmon escapement began to increase. In 2009 it was estimated to have reached over 500,000 in SPC alone and 1.2 million in the Puyallup watershed, which is 63x the "biological escapement goal" set in the 1970s. Because of long generation time for steelhead, only one brood year exposed to the increasing pink escapement has returned to date. Based on the one complete brood return, and partial returns from subsequent broods, the steelhead population is responding positively to the increased pink escapement.

## D. Early marine migration patterns of Coastal cutthroat trout (*Oncorhynchus clarki clarki*), steelhead trout (*Oncorhynchus mykiss*), and cutthroat x steelhead hybrid smolts

Megan Moore, NOAA Fisheries

Hybridization between steelhead or rainbow trout (*Oncorhynchus mykiss*) and coastal cutthroat trout (*Oncorhynchus clarki clarki*) has been documented in several streams

along the North American Coast, where the two species occupy similar habitats. Intermediate morphological, physiological, and performance traits have been attributed to hybrids of cutthroat and steelhead, though little is known about hybrid behavior. This study used acoustic telemetry to record migration patterns ('tracks') of 52 cutthroat, 42 steelhead x cutthroat hybrid, and 89 steelhead smolts, starting with entry into the Big Beef Creek estuary and subsequent movement into the Hood Canal (part of Puget Sound). Median hybrid residence time, estuary time, and tortuosity values were intermediate in relation to median values of the same track parameters for the pure species. The median total track distance measurement was higher for hybrid smolts than for both cutthroat and steelhead smolt groups. At the end of each track (i.e., last detection), most steelhead smolts were located north of the Big Beef Creek estuary along their seaward pathway. Cutthroat tracks grouped more closely to the estuary (both north and south) than did steelhead tracks. Individual hybrids behaved similarly to either cutthroat or steelhead, but some exhibited novel dispersal patterns. Hybridization events appear to significantly affect migration patterns of Big Beef Creek steelhead and cutthroat populations and could affect the productivity of both species.

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