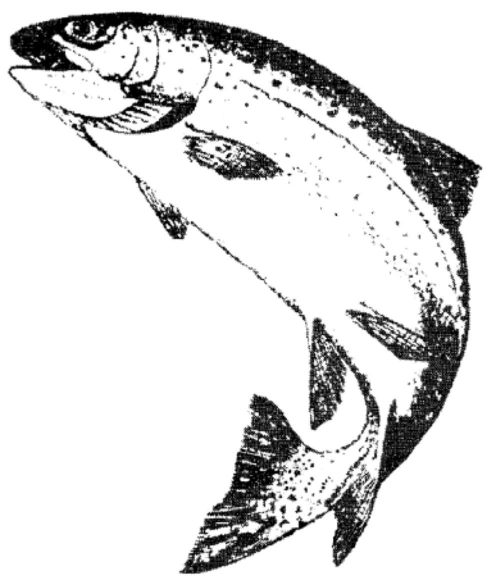
SUMMARY OF
THE ELEVENTH

PACIFIC COAST STEELHEAD MANAGEMENT MEETING



March 4-6, 2008
Oxford Suites – Boise, Idaho

Sponsored by:

Pacific States Marine Fisheries Commission

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U.S. Fish and Wildlife Service

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Pacific Coast Steelhead Management Workshop

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I. Summary

Meeting Chair: Bob Leland, Washington Department of Fish and Wildlife;
Stephen Phillips, Pacific States Marine Fisheries Commission

The Pacific States Marine Fisheries Commission (PSMFC), with support from the U.S. Fish and Wildlife Service Sport Fish Restoration Program, sponsored the 11th workshop on steelhead (*Oncorhynchus mykiss*) management. The workshop, held in Boise, Idaho was attended by some 60 Pacific Coast fisheries managers, researchers and other interested parties from the states of Alaska, Washington, Idaho, Oregon, and the province of British Columbia.

Topics for the workshop included:

- steelhead stock status and the Endangered Species Act
- historical steelhead abundance estimation methods
- technology applications for steelhead studies
- Idaho steelhead - genetic diversity, parr and smolt yield, migration timing, and age structure
- steelhead life history, biology and modeling

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 steelhead age structure, the importance of repeat spawners, historical spawning distribution, and escapement goals for salmon and catch-and-release fisheries. In addition, a poster session was held on various topics including natural reproductive success of hatchery steelhead, the use of GPS and handheld computers to monitor steelhead populations, and the use of habitat conditions to formulate the parameters of a density-dependent stock-recruitment function.

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/steelhead2008/.

Bob Leland, of Washington Department of Fish and Wildlife was presented an award from the Pacific States Marine Fisheries Commission in appreciation of outstanding service to the Pacific Coast Steelhead Management Meetings.

Members of the Workshop Steering Committee were:

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
Bob Leland, State of Washington
Robert Bison, Province of British Columbia, Canada
Grant Kirby, Northwest Indian Fisheries Commission

II. Steelhead Stock Status Review by Jurisdiction

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.

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. 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 is in the process of developing a 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.

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. Preliminary results of an otolith strontium-to-calcium (Sr:Ca) ratio analysis in steelhead/rainbow trout collected within several Central Valley streams indicate that anadromy is most prevalent in unregulated streams, and up to 95% of the fish collected below impassible dams did not exhibited anadromy. The Department of Fish and Game also is developing a Coastal Salmonid Monitoring Plan with assistance from NMFS.

Data gathered from the Steelhead Fishing Report-Restoration Card program (http://www.dfg.ca.gov/fish/Fishing/Monitoring/SHRC/index.asp) suggest that steelhead populations have likely improved for the north coast and Central Valley, and on a statewide basis, anglers are catching more steelhead (wild and hatchery combined) per trip, particularly on the coastal rivers. Since 1998, angler effort shifted from the Northern and Central California steelhead DPS to the Central Valley DPS. Steelhead anglers continued to release the majority of their steelhead (including hatchery steelhead). Since 1999, averages of 1.5 times more wild steelhead have been caught statewide than hatchery steelhead.

Based on the limited data available and sport angling results, it appears that California's wild steelhead populations range from stable to possibly improving.

B. Oregon

Kevin Goodson, Oregon Department of Fish and Wildlife

The last statewide status assessment of Oregon's steelhead populations was the 2005 Oregon Native Fish Status Report. Oregon's presentation will review the findings of this assessment, provide summaries of viability assessments completed for the four federally listed steelhead Distinct Population Segments (DPS), and highlight some of the monitoring efforts that are underway in Oregon.

2005 Oregon Native Fish Status Report

A summary of the 2005 Oregon Native Fish Status Report was given at the 2006 Pacific Coast Steelhead Management Meeting. The entire report can be found on ODFW's website at: http://www.dfw.state.or.us/fish/ONFSR/index.asp. Monitoring information since 2005 suggests that the status of the non-listed steelhead management units in Oregon has not changed significantly from the 2005 assessment.

Recovery Planning Results

Oregon is currently taking the lead in the process to develop three Endangered Species Act (ESA) Recovery Plans for listed steelhead DPSs (Mid-Columbia River, Lower Columbia River and Upper Willamette River). A public draft of the Oregon Mid-Columbia River Recovery Plan will be available for review in the spring of 2008. Completion of a public draft of the Oregon Lower Columbia River Recovery Plan is targeted for December of 2008, and a draft of the Upper Willamette River Recovery Plan will come out sometime in 2009. A timeline for the Snake River Recovery Plan process is in flux, with staff from the National Oceanic and Atmospheric Administration taking the lead for the entire plan.

Viability status assessments have been completed by the federal Technical Recovery Teams (TRT) for each DPS, strata/major population group, and population. In the Mid-Columbia River DPS, two of the twelve historic Oregon populations were found to be extinct, one was at high risk of extinction, six were at moderate risk of extinction, two were found to be viable (low risk), and one was highly viable (very low risk). In the Lower Columbia River DPS, one of the six historic Oregon populations was found to be at very high risk of extinction, two were found to be at high risk, two were at moderate risk, and one was found to be viable (low risk). Of the four historic populations in the Upper Willamette River DPS, three were found to be at moderate risk of extinction and one was found to be viable (low risk). Status assessments for the Snake River populations have not been finalized.

Recovery scenarios for each of the three major population groups in the Mid-Columbia River DPS have also been defined. These scenarios fulfill the obligation in a federal ESA recovery plan to identify what level of risk the major population groups and individual populations must achieve for the DPS to be considered viable. In addition to the recovery scenarios, the recovery plan also identifies objectives for broad sense recovery. The broad sense recovery goal is the long-term goal for the recovery plan. Recovery scenarios and broad sense recovery objectives for the Lower Columbia River and Upper Willamette River DPSs have not been finalized.

Steelhead Monitoring

Oregon continues to make progress in implementing steelhead monitoring strategies. Three programs have been developed to monitor steelhead spawners, juveniles and habitat. Information collected through these efforts allows ODFW to assess elements of steelhead abundance, productivity, spatial structure and diversity. These programs utilize a probabilistic sampling strategy which provides a frame of spatially balanced survey sites to draw from annually that allows for estimates to be made with a reasonable degree of accuracy at various spatial scales, depending on the sampling intensity. This approach allows the monitoring effort to be adjusted in conjunction with funding availability while maintaining the ability to monitor at the DPS level at a minimum. Oregon will identify additional steelhead monitoring needs in recovery and conservation plans that are being developed. Funding will then be sought to meet these needs.

Spawning surveys are conducted on a regular basis throughout the spawning season. Redds are marked and enumerated with a cumulative total provided at the end of the season. These surveys have been calibrated with nose counts of steelhead at various locations where these surveys have been implemented. Spawning surveys are currently conducted throughout the Klamath Mountain Province (KMP) and Oregon Coast DPSs. Surveys are also being conducted in the John Day Basin.

Juvenile steelhead data is collected during summer snorkel surveys targeted at coho juveniles. Pools in small to moderate sized streams are snorkeled throughout the distribution range of coho and provide information on the presence and density of steelhead juveniles. This information cannot be used to estimate juvenile abundance, but does provide insight into trends. Summer juvenile steelhead monitoring currently occurs throughout the KMP, Oregon Coast and Lower Columbia River DPSs.

Habitat surveys are conducted throughout the range of steelhead distribution. Numerous habitat components are inventoried within random stream segments. This information can be used to assess the condition of key habitat elements and provides the means to assess trends in steelhead habitat conditions with a reasonable degree of sensitivity. Steelhead habitat monitoring currently occurs throughout the KMP, Oregon Coast and Lower Columbia River DPSs.

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. From 1975-79, the steelhead run at Lower Granite Dam averaged 59% naturally-produced fish and from 1985-89, the run averaged 24% naturally-produced fish. From 1990-99, the run averaged 13% naturally-produced steelhead. Since 2000 the run has averaged 15% naturally produced fish. The average steelhead escapement at Lower Granite Dam since 2000 has been 164,000 and 24,000 total and natural adults, respectively.

D. Washington

Amilee Wilson, Washington Department of Fish and Wildlife

Washington State is divided into seven steel-head Distinct Population Segments (DPSs) designated 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. According to the Department of Fish & Wildlife (WDFW) Salmonid Stock Inventory (SaSI), the Olympic Peninsula alone has twenty-two *Healthy* stocks, six *Depressed* stocks, and twenty-one *Unknown* stocks of steelhead. This DPS has maintained the highest number of healthy wild steelhead stocks in Washington State.

The Lower and Middle Columbia River DPSs as well as the Snake River Basin DPS are listed as *Threatened*. These areas contained the highest number of *Depressed* or *Unknown* stocks (mainly summer steelhead stocks) within Washington State.

The Upper Columbia River ESU is listed as *Endangered* by NOAA. The few steelhead stocks present are rated *Depressed* or *Unknown*.

On May 11, 2007, the most recent federal listing occurred for steelhead stocks that reside in the Puget Sound DPS (72 FR 26722). This DPS was listed as *Threatened* under ESA. According to SaSI, only five salmonid stocks are rated *Healthy*, nineteen stocks are rated *Depressed,* one stock is rated *Critical*, while twenty-seven stocks are rated *Unknown* due to the lack of adequate abundance trend data to rate status.

To restore and preserve this important resource, WDFW initiated a multi-phrase process to improve the management and status of steelhead. The first phase came with the WDFW Director's challenge to develop a steelhead science paper for subsequent development of management plans. In 2006, the Department released their steelhead science paper for public comment and in February 2007 released this updated document to the Fish & Wildlife Commission (FWC).

The second phase of the process began in July 2006 with the formation of a public ad hoc stakeholder group to help the Department develop the Statewide Steelhead Management Plan (SSMP). This document provides a framework of policies, strategies, and actions for steelhead management throughout the state and will be presented to the FWC for adoption in March 2008. Recognizing that substantial variation exists in status of stocks, habitat conditions, and tribal, local, and federal authorities across the state, the objective of this document is to guide WDFW in the development of the third phase, the Regional Management Plans (RMPs).

In conclusion, WDFW will continue to work through this important multi-phase 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. British Columbia

Robert Bison, BC Ministry of Environment

Within the geographic range of steelhead in BC, there are about 1200 watersheds that are greater than 3rd order that flow into the ocean, an estuary, or a large river. Of these, an estimated 391 watersheds contain 423 steelhead stocks (Parkinson 2005). The stocks can be grouped according to their ancestral lineages as evidence by molecular genetic studies and are referred to as "major phylogenetic groups" (MPG's). Following the last glacial period, stocks located along south coast areas of BC were colonized from a glacial refugium located in coastal areas of present-day Washington State and are referred to as the South Coast MPG. Stocks located in the south interior areas of BC were colonized from interior areas of the Columbia River watershed and are referred to as the South Interior MPG. Stocks located in the north half of BC were colonized from the Queen Charlotte Islands which were ice free during the last glacial period and are referred to as North Coast MPG. Among these three groups are two "transition" groups that reflect post glacial genetic mixing. One additional group consists of a single summer run stock, the Alsek stock, which may have been colonized from the Berring Refuge as is evidenced for steelhead and rainbow stocks from Alaska and Kamchatka (Parkinson 2005; McCusker et al. 2000). Dividing these 5 MPG's into summer and winter run timing groups results in 9 groups. Dividing these nine groups into major drainages results in 27 conservation units (CU's).

In fisheries, reference points that describe the status of fish stocks are usually defined in terms of abundance reference points and/or fishing rate reference points (eg. Bmsy and Fmsy). For BC steelhead, reference points are defined in terms of <u>abundance</u>. More specifically, these reference points are defined in terms of carrying capacity from which two abundance thresholds are derived: a conservation concern threshold (CCT) and a limit reference point (LRP). These two relative abundance thresholds delineate 3 ranges of abundance ("zones") that describe status: Routine Management Abundance (or "zone"; RMZ), Conservation Concern Abundance (CCZ), and the Extreme Conservation Concern Abundance (ECCZ). The relative abundance of the CCT is 30% of carrying capacity and the relative abundance of the LRP is 10% of carrying capacity. Above 30% of carrying capacity is considered to be RMZ, between 10%-30% is considered to be CCZ, and less than 10% is considered to be ECCZ. The development of these thresholds and zones were intended to guide management so as to maintain stocks in the RMZ. The LRP was defined as the abundance from which a stock could recover to the RMZ within one generation if all sources of mortality were removed. Falling below the LRP would result in a more prolonged recovery and thus a prolonged loss of fishery benefits. One of the technical assumptions implicit in this approach is the assumption that all density dependent processes occur prior to smolting and that smolt to adult survival is density independent. Given apparent shifts in marine survival, most notably a 4-fold decline that occurred in the early 1990s, the simplest and most direct measure of status is to estimate current smolt output relative to smolt carrying capacity. Alternatively, reference points described in term of adults depends on assumptions about marine survival. For example, if a stock and recruitment times series only spans years relatively low marine survival, adult carrying capacity must be rescaled to "average" marine survival as defined in the policy analysis (Johnston et al. 2000) in order to derive the CCT and LRP.

Technically, the estimation of carrying capacity for individual stocks has proven challenging in BC. There are few sites where abundance estimation of adult or smolts is either possible, precise enough, or of sufficient duration to estimate smolt carrying capacity empirically with useful precision. But the number of relatively precise adult estimation sites is slowly growing, particularly with the growing use of electronic fish counters. At present, there are 4 fully operational resistivity counters in BC that monitor steelhead (and salmon) abundance. Three are located in the South Coast and South Interior MPG's (Keogh, Deadman, and Bonaparte) and one is located in the North Coast MPG (Kloya). Steelhead fence operations currently ongoing include one in North Coast MPG (Sustut) and one in South Coast MPG (Little Campbell). Overall, the vast majority of adult abundance estimation or monitoring is done by periodic visual counts during the over-summering period for some early summer run stocks or periodic counts during spawning time, where the uncertainty in the spawner abundance data becomes a technical issue when attempting to empirically estimate carrying capacity. Estimation of smolt output monitoring sites has also proven challenging. There have been many short term projects over the past 30-40 years, but most too short in duration and/or too imprecise to be useful for estimation of smolt carrying capacity. There are 4 presently in continuous operation, all in the South Coast MPG (Cheakamus, Coquitlam, Alouette, Keogh). The Keogh adult/smolt abundance time series is the longest spanning 31 years. The Keogh produces roughly 220-230 smolts/km at capacity (B. Ward, pers. comm.). To date and in the absence of direct empirical estimates, estimation of carrying capacity for some of BC's steelhead stocks has been derived from assessments based on quantifying the amount of freshwater habitat and transposing these into measures of maximum fry, parr, smolt or adult capacity (Tautz et al. 1992, Riley et al. 1998). Yet others have been derived from adult stock and recruitment relationships as evidenced by time series' of reported sport fishing catches (Lill 2002). In the absence of alternatives, these "estimates" have been used and have been combined with estimates of current abundance (often fry or adult abundance assessments) to assess status.

The geographic distribution of the status of 21 CU's shows that abundance in the southern third of BC continues to be low, classified as either Conservation Concern or Extreme Conservation Concern. Stocks along the west coast of Vancouver Island have maintained a higher status due to more favorable smolt to adult survival rates. In the northern two thirds of BC, the abundance status is classified higher still, the vast majority of stocks classified as Routine Management abundance, however there is evidence of a recent downward trend or shift in abundance of major runs like Dean, Skeena and Nass occurring or starting about 4 years ago. Recent trends in pacific salmon stocks in the Skeena have shown similar responses with lower than expected returns of sockeye, coho and some chinook stocks in the last 4 years. The northerly extent of this trend or shift is not known for steelhead. Available information is too scant for stock groups like the Stikine and Taku.

A trend in the spatial distribution of sport fishing effort over the past 4 decades corroborates with various fishery independent measures of abundance and trends. In general, steelhead angling effort has trended northward focusing particularly on the Skeena River stocks. Also, steelhead angling effort has also become increasingly focused on streams stocked with hatchery steelhead of which there are currently 10 streams in BC. A single fishery, the Chilliwack River steelhead fishery, a fishery stocked with hatchery fish and one where hatchery steelhead harvest is permitted, accounted for 35% of the BC steelhead angling effort in 2006.

F. Alaska

Peter Bangs, Alaska Department of Fish and Game

Steelhead *Oncorhynchus mykiss* are found in coastal streams of Alaska from Dixon Entrance in Southeast Alaska, north through the Gulf of Alaska to the Alaska Peninsula in Southwest Alaska. The length of steelhead streams documented in Alaska's Anadromous Waters Catalog totals 4,202 km, 63% of which is located in Southeast Alaska. Most steelhead populations are believed to be small with annual escapements of less than 200 fish. Long-term weir counts (i.e., five or more years of data) are available for six streams in Alaska. Three of the six streams (Ayakulik River, Sitkoh Creek, and Sashin Creek) had weir counts in 2007 that were below their median levels. The remaining three streams (Situk River, Litnik River, and the Karluk River) had weir counts in 2007 that were above their median levels. Snorkel surveys are conducted annually on steelhead index streams in southeastern Alaska. Of the eight streams where surveys were successful in recent years, all had counts in 2007 that were equal to or above median levels. The lack of monitoring or stock assessment for the vast majority of steelhead streams in Alaska makes it difficult to infer trends in population health or status on a statewide basis. However, our "best guess" as to the general status of most steelhead stocks in Alaska, based on the limited stock status information and anecdotal information from anglers, is that stocks appear to be relatively stable. The limited monitoring efforts on steelhead populations in Alaska underscores the importance of protecting habitat and ensuring that harvest levels are sustainable.

III. Historical Abundance Estimation Methods

Session Chair: Nick Gayeski, Washington Fish Conservancy

A. Wild Winter Steelhead Run Timing: How It Has Been Reshaped by Fisheries Management in Washington

Bill McMillan, Wild Salmon Center

Beginning in 1962, winter-run hatchery steelhead returns substantially increased throughout western Washington. A high proportion of these hatchery returns occurred in December and January with a range from November to April. To address mixed-stock fishery concerns, Washington's early-return winter steelhead have been managed for up to 95% exploitation rates under the assumption this provides differential harvest on hatchery steelhead and protects wild steelhead. The questions examined in this presentation are: what proportion of the wild steelhead catch historically occurred from November through February; what changes in wild steelhead run timing have resulted since hatchery return increases and high harvest rates targeted on early return steelhead; and what other life history attributes related to early run timing might have been affected? To answer these questions historic tribal steelhead fishery records from 1934 to 1959 were examined for 10 Washington steelhead rivers, an historic period when Washington steelhead were primarily wild. The steelhead sport catch records dating to 1948 in Washington were also examined. These historic data were compared with more modern catch and run-size data. Although catch data do not provide a complete view of steelhead run timing, it was found that wild steelhead that made river entry prior to the end of February were historically very abundant but no longer are.

B. Washington Wild Steelhead Historic Abundance and Recovery Parameters

Pete Soverel, Wild Salmon Center

Historically, Washington coastal and Puget Sound steelhead were extraordinarily abundant. River stocks displayed a very wide range of run-timing and life history variability. Currently, wild steelhead populations:

- Are very depressed compared to historic abundance (typically 1%-5% of historic abundance). Examples – Puget Sound, Hoh and Queets (both of which have substantial percentages of their watersheds in pristine condition)
- Run-timing have been dramatically altered
- Many life-history strategies are either absent altogether or much reduced
- Population trends continue to decline

Wild steelheads have demonstrated substantial ability to recover rather quickly:

- Puget Sound 1932-1950's
- Sustut River 1930's-present
- Kvachina/Utkholok Rivers 1994-present

Recoveries share common features:

- Absence of hatchery fish
- Restricted or no harvest

Present escapement goals (typically very small fractions of historic abundance) and management regimes (continued hatchery introductions and targeted harvest of early run-timed populations) insure wild steelhead cannot recover to healthy levels.

IV. Technology Application for Steelhead Studies

Session Chair: Fred Goetz, U.S. Army Corps of Engineers

A. Trade-Offs Associated With Alternative Egg Collection Strategies for Salmon and Steelhead Conservation Hatcheries

Barry Berejikian, Dmitri Vidergar and Josh Gable, NOAA Fisheries

Traditional salmon hatchery operations involve collecting maturing adults, spawning them in the hatchery and releasing offspring. Conservation hatcheries that include captive rearing from egg to the smolt or adult stage require the development of new approaches to balance production and genetic factors. The collection of eyed eggs from naturally produced redds represents one approach that has been implemented for ESA-Threatened Chinook salmon and steelhead in the Pacific Northwestern United States. For the three programs (representing six populations) we summarized, the number of eggs collected was close to the number needed for the program. A high percentage of the eggs (mean ± SD) collected from individual redds were viable (steelhead: 94.5% ± 11.6%; Chinook: 94.8% ± 5.8%), reflecting high natural fertilization success and viability to the eyed stage. Eggs collected from individual redds were infrequently damaged (steelhead: 0.2% ± 0.6%; Chinook: 4.5% ± 6.8%) as a result of the hydraulic sampling process. The mean survival of eyed eggs to first feeding in the hatchery was very similar for steelhead (94.6%) and Chinook salmon (95.6%). Approximately 70% of the eggs not collected during hydraulic sampling in a spawning channel were collected as emergent fry, further suggesting a low impact to eggs remaining in the redds. However, the potential mortality of eggs remaining in hydraulically sampled redds has not been experimentally evaluated under natural conditions. For several recent captive populations of Chinook salmon and steelhead a much larger proportion of the wild parent population has been represented in the captive population than would have been achieved by artificial spawning to produce the same number of eggs. The egg collection approach has thus far provided a mechanism to increase genetic variability in captive populations over conventional approaches, while not collecting more eggs than necessary for the programs and leaving a portion of the naturally produced embryos in the natural environment.

B. Early Marine Survival and Behavior of Steelhead (*Oncorhynchus mykiss*) Smolts through Hood Canal and the Strait of Juan de Fuca

Megan Petrie, Skip Tezak and Barry Berejikian, NOAA Fisheries

Marked declines in Hood Canal and Puget Sound steelhead populations have been detected in the last 10 to 20 years, and have been shown to contrast markedly with the relatively stable condition of populations along the Washington and Oregon coasts. This discrepancy between the health of Coastal as opposed to Puget Sound steelhead populations suggests that near shore smolt migration may constitute a major cause of mortality. Acoustic telemetry was used to investigate survival, migration timing, and migratory behavior of steelhead smolts during two consecutive out migrations. In 2006, smolts (n = 159) from four Hood Canal streams (Big Beef Creek, Dewatto River, Skokomish River, and Hamma Hamma River) and one stream feeding into the Strait of Juan de Fuca (Snow Creek) were monitored, while a greater number of smolts (n = 187) from the same Hood Canal streams were studied in 2007. Fish from the Hood Canal streams included four wild populations and one hatchery population, which originated from the Hamma Hamma River. Estimated survival rates for wild and hatchery smolts from river mouths to the northern end of Hood Canal ranged from 67% to 85% in 2006, and from 64% to 84% in 2007 (Fig.1). For the migration from the north end of Hood Canal to the Strait of Juan de Fuca, estimated survival rates ranged from 23% to 49% in 2006, and are forthcoming for 2007.

The one hatchery-reared population exhibited migration characteristics within the range of those of the wild populations, though estimated survival rates were significantly lower when the entire migration from river mouth to the Strait of Juan de Fuca was considered. In 2006, travel rates through Hood Canal (x = 8.0 km/d) were significantly lower than those observed in the Strait of Juan de Fuca (x = 25.7 km/d). Residence time and migration patterns within Hood Canal were highly variable within and among populations. The extended duration of residence in Hood Canal exhibited by some fish suggests that it may provide growth opportunities and function as more than simply a migration corridor. Receivers positioned in nearshore habitats did not detect a disproportionately large number of migrants, indicating that migration was not preferentially taking place along the shoreline. Detailed knowledge of steelhead survival and patterns of nearshore habitat use not only aid in determining causes of population decline, but also help define extinction risk and recovery actions for this ESA-listed species.

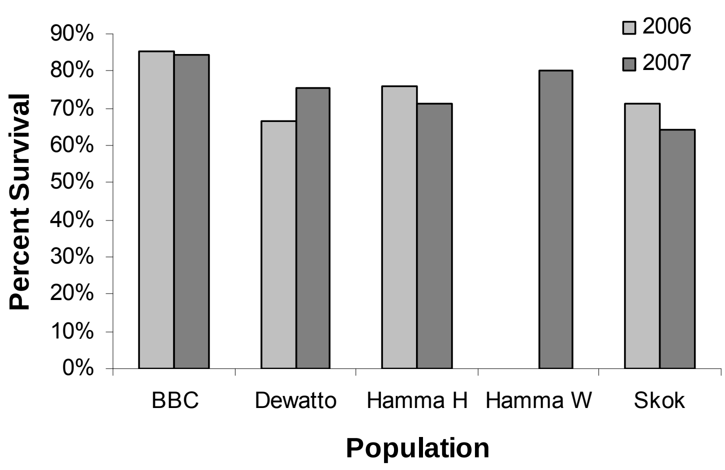

Figure 1: Survival estimates for smolts migrating through Hood Canal during the years 2006 and 2007. Tagged fish populations include Big Beef Creek (BBC), the Dewatto River, Hamma Hamma Hatchery (H), Hamma Hamma Wild (W), and the Skokomish River (Skok).

C. Migratory Behavior of Hatchery and Wild Steelhead Smolts in Puget Sound as Measured by Acoustic Telemetry

Fred Goetz, U.S. Army Corps; Sayre Hodgson, Nisqually Tribe; Bob Leland, Washington Department of Fish & Wildlife; Ed Connor, Seattle City Light; Russ Ladley and Andrew Berger, Puyallup Tribe

In the Puget Sound, a collaborative telemetry network has been developing that allows monitoring of acoustic tagged fish at multiple scales from - individual streams, to Puget Sound-wide (2500 miles of shoreline), and along the North American coast-line. The collaboration includes a wide variety of organizations and more than 40 investigators or collaborating staff. We will present data on the first year of a multi-year monitoring program of hatchery and wild steelhead smolts migrating from large rivers in eastern Puget Sound. Objectives of our work were to conduct intensive study of 3 stocks in the Green River and provide a summary comparison with releases from three other rivers. Specifically we compared 1) the relative survival, migratory behavior and habitat use between upper Green River releases(R Km 100 and 104) with hatchery (H) and wild (W) smolt releases in the middle Green River (R Km 53-55); and 2) show summary results comparing releases from the Green, Puyallup (W and H), Nisqually (W) and Skagit (W) Rivers.

In the Green River, a total of 200 steelhead smolts were tagged in three release groups - upper Green River (UG) wild broodstock released above (n=50) and below (n=50) a flood control dam; Middle Green (MG) River releases with 50 fish from Soos Creek hatchery (H) and 50 wild (W) smolts. The UG releases covered twice the migration distance of the MG releases, approximately 100 km for UG and 55 km for MG. Diel migration patterns changed from upper river to estuary with 90% of movement at night in the upper river and less than 35% at night upon river exit. Travel time through the river was fastest for W (10 days), intermediate for H (11.6), and slowest for UG (12.2). Travel rates in the river showed that non-leveed areas had longer residence times for tagged fish than leveed areas. Relative survival (detection rate) was fairly consistent for all release groups – within Green River detections were - 81% UG, 86% H, and 88% W; in the Duwamish estuary 76% UG, 78% H and 78% W; in nearshore – 48% UG, 46% H, and 54% W; outside Puget Sound - 6% UG, 4% H and 4% W (Fig. 1). Unlike MG releases UG fish were detected at two pathways to the Pacific, the Strait of Juan de Fuca and Keogh R at N Vancouver I.

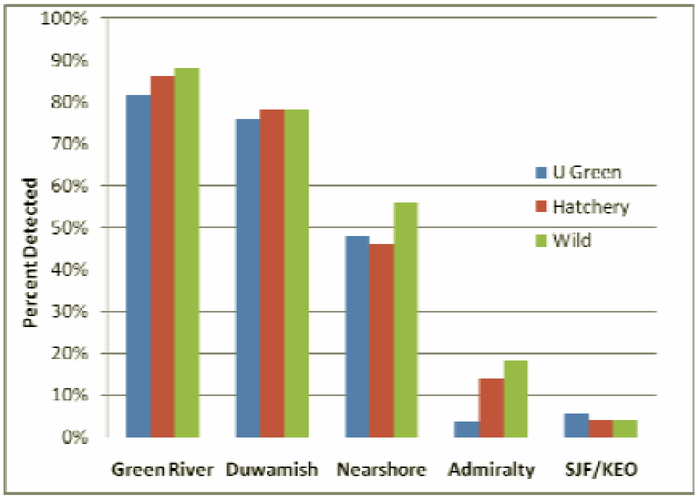

Figure 1. Comparison of detection rates for 3 release groups in the Green River. SJF/KEO is receiver lines at the Strait of Juan de Fuca (SJF) and Keogh River (KEO).

For all Puget Sound river releases, there was a general similarity for detection rates from the river to the estuary - 1) six release groups in the Puget Sound ranged from 75-86%, and 2) four release groups in Hood Canal ranged from 78-98%. There were slightly higher detection rates in Hood Canal, where the migration distance from release to estuary was significantly shorter than Puget Sound rivers. The average travel time of Puget Sound releases to the mid-point of the Strait of Juan de Fuca (SJDF) was 19 days (range of 9-22 days/release group). Travel rates for individual fish ranged from 6 to 26 km/day. Detections at the SJDF showed a 75% lower detection rate for hatchery groups (4-6%) relative to 3 of the 4 (15-18%) wild group detections. Only one wild group, MG W had an equal detection rate (4%) to two of the hatchery groups, Puyallup and MG.

D. Using Acoustic Telemetry Technology to Compare the Migration Timing and Survival of Hatchery-Reared and Naturally-Reared Steelhead Smolts in the Alsea River, Spring 2007

Steve Johnson, Oregon Department of Fish and Wildlife (Retired)

The objectives of the study were to (1) Determine if there are differences in the in-river and estuarine survival of two hatchery reared groups and one naturally reared group of winter steelhead smolts in the Alsea River, and (2) Determine if these three groups of smolts differ in their spatial and temporal used of in-river and estuarine habitat as they migrate to the ocean.

Three groups of steelhead smolts were implanted with acoustic transmitters. Two groups were from hatchery steelhead raised at the North Fork Alsea Hatchery. One hatchery group is the progeny of the traditional Alsea River broodstock initially developed in the 1950's. The second hatchery group is the progeny of unmarked Alsea adults that were captured in the Alsea River by volunteers beginning in the winter of 2000-01. The third group of steelhead smolts that was tagged was from naturally reared smolts captured in a downstream migrant trap placed in Crooked Creek (tributary of the N. Fork Alsea). The hatchery smolts were tagged between 3/27/07 and 3/29/07. A total of 74 smolts were tagged from the “traditional” hatchery brood, and 76 smolts were tagged from the “new” broodstock. A volitional release of steelhead smolts (untagged and tagged fish) from the North Fork Hatchery began on 4/2/07. Naturally reared steelhead smolts were captured in a downstream migrant trap in Crooked Creek. The trap ran continuously from March 6 through May 8. Seventy two steelhead smolts were tagged between March 17 and April 18. All naturally reared steelhead were held for 24 hours after tagging and then released.

Thirty-one acoustic receivers were located throughout the Alsea River, estuary, and in the ocean offshore of the mouth of the Alsea River mouth in order to track the movement of the smolts. The receivers were deployed in mid-March and removed in late June.

Results indicate that 80% of the tagged traditional hatchery brood group migrated to the head of tide, compared to 71% of the “new” hatchery brood and 74% of the naturally reared smolts. The lower number of smolts migrating to the head of tide in the “new “ broodstock and naturally reared smolt groups may be partially the result of smaller fish that did not migrate, rather than direct mortality.

Results indicate estuary survival (percent of the fish that made it to the head of tide that were last observed at the estuary mouth) was 44% for the traditional hatchery group, 59% for the “new” hatchery group, and 53% for the naturally reared smolt group.

Survival of the tagged fish from the site of release to ocean entrance was 35% for the traditional broodstock group, 42% for the “new” broodstock group, and 39% for the naturally reared smolt group. While “post-release” survival is often referred to as ocean survival, these results indicate that much of the “post –release” mortality of the steelhead smolts in the Alsea basin is occurring prior to ocean entrance.

E. PIT Tagging of Steelhead Smolts and Adults for 5 Years at Sitkoh Creek, Alaska

David Love, Alaska Department of Fish and Game

The Alaska Department of Fish and Game, Division of Sportfish has been annually counting and uniquely tagging all immigrant adult steelhead and emigrant smolts since 2003 as the fish migrated through a standard picket weir located near the mouth of Sitkoh Creek, southeastern Alaska. The objectives of this project include collecting biological parameters necessary to describe smolt and adult production for a relatively pristine population of steelhead. As adults and smolts passed through the weir, they were counted, tagged with 134.2 kHz passive integrative transponder (PIT) tags, measured, sexed and systematically sampled for scales. Recaptured PIT-tagged fish were scanned using handheld scanners and a PIT-tag antennae located in the entrance cone of the upstream trap. The PIT tag antennae only detected about 60% of the tagged fish entering the trap due to interference problems. Freshwater ages from systematically-sampled smolt have been estimated using triplicate reads of randomized, digitally-captured scale images, and agreement within and among scale-reading technicians has been high (>90%). Previously PIT-tagged steelhead smolts have been returning as adults since 2005. Ocean-age validation based on scales from these recaptured fish has yielded highly repeatable results (>80% for maiden run, repeat and skip spawning adults combined). Total maiden (first time spawner) ocean ages have been estimated with slightly better agreement in equivalent 2 out of 3 scale ageing reads for fish initially tagged as smolts that were recaptured in 2005-2007 (>83% in 2 out of 3 independent scale reads). Although our scale ageing methodology appears to be repeatable, further work is needed to validate accuracy of current freshwater scale ageing methods. Combining freshwater ageing of smolts and known ocean ages of returning adults has allowed preliminary smolt assignment to adult brood class and smolt-per-spawner estimates (preliminary estimate of 2.5 smolt-per-spawner based on 2, 3 and 4 freshwater) as well as preliminary adult-adult survival (estimated 91 adults returning so far from the 2003 escapement that were 2 fresh and 2 ocean).

V. Contributed Posters

Session Chair: Patricia Michael, Washington Department of Fish and Wildlife

A. Natural Reproductive Success of Hatchery Steelhead: Implications of Recent Findings

Pat Hulett, Washington Department of Fish and Wildlife

Multiple studies involving several stocks of summer and winter steelhead in Oregon and Washington have forged a fairly broad acceptance of the key result that these studies have in common. Specifically, that naturally spawning steelhead from conventional (multi-generational) hatchery stocks produce substantially fewer offspring than do their wild counterparts. Likewise, more common reference to such stocks as “domesticated” reflects the belief that domestication selection (adaptation to the environment and process of artificial culture) has altered these stocks. However, the hatchery stocks in question have origins that differ from the wild fish to which they have been compared. Hence, domestication may well not be the sole cause of the observed low reproductive performance. Stock source, and in some cases inbreeding and intentional artificial selection, may also be contributing factors. Regardless, hatchery reform assessments have widely prescribed switching to the use of local wild brood stocks for hatchery production. That rationale leans heavily on the supposition that the locally derived stocks would undergo no more than minor changes from domestication or other genetic processes. That would then permit an integrated (interbreeding) population of wild and artificially cultured fish to be maintained without significant risk to the wild stock. Initial results from the study of such an integrated population in the Hood River found no significant differences in reproductive success of the hatchery and wild fish, as measured by their production of adult offspring. Reactions to those findings were mixed. Some expressed concern that fitness reductions from a single generation of artificial culture could be as high as 33% (i.e., hatchery fish producing 67% as many offspring as wild, per spawner). Others considered the non-significant results to be evidence that artificial culture had little effect on reproductive success. The apparent discrepancy stems from the finding that point estimates of reproductive success (hatchery, as a percent of wild production per spawner) ranged widely from 67% to 156%, but none of them were different statistically from a finding of 100% (hatchery = wild). Subsequent findings for the same population reported less equivocal differences in which hatchery fish produced 85% of that of wild fish overall across six brood years. That study reported an even greater reduction in fitness when returning hatchery fish were used as spawners in a subsequent generation of artificial production. These results suggest judicious caution in the use of integrated hatchery production, especially regarding inclusion of hatchery fish as broodstock for hatchery production. They also highlight the need to understand the causes of reduced reproductive performance of hatchery stocks spawned from local wild broodstocks. We further need to discern the implications of production by non-anadromous spawners and production of non-anadromous offspring in these populations. Additional work in the Hood River, as well as results from other studies such as those ongoing in the Kalama River in SW Washington and Little Sheep Creek in NW Oregon, are needed to understand how to manage risks that hatchery production programs pose to wild populations.

B. John Day River Steelhead: In Through the Out Door

Tim Unterwegner and Jim Ruzycki, Oregon Department of Fish and Wildlife;
Steve Anglea, Biomark

The John Day River is one of the longest free flowing rivers in the lower 48 states and is managed exclusively for wild anadromous fish production. Although no releases of hatchery fish occur in the basin, recent evidence suggests a relatively high percentage of returning adult steelhead are of hatchery origin. Detections in the migration corridor also suggest that John Day fish stray from their natal watershed. We began tagging wild juvenile steelhead in 2001 with Passive Integrated Transponder (PIT) tags in an effort to determine smolt to adult survival (SAR) and track movement of juveniles and adults. Tracking was accomplished using the Columbia River PIT tag information system (PTAGIS). This system allows us to track the movement of tagged fish as they are detected at antennas throughout the Columbia River basin. To date, 13,910 wild juvenile steelhead have been tagged in the John Day River and 307 returning adults detected at Bonneville Dam, the lowermost dam on the Columbia River.

In September 2007, a prototype antenna array was installed by Biomark Inc. on the John Day River, with the primary purpose of determining the incidence and origin of stray steelhead. SAR of John Day River steelhead to Bonneville Dam has varied from 1.4% to 2.9%. Observations from recent surveys in the basin indicate that 29–41% of adults throughout the basin are of hatchery origin. Greater than 50% of returning John Day origin steelhead passes over McNary Dam which is 74 miles upstream of the mouth of the John Day River. Hatchery steelhead straying into the John Day primarily originate from Snake River releases and so far, these stray fish were primarily transported as smolts in barges down the Snake and Columbia River corridors. Our evidence indicates clear exchange of steelhead among populations of the Columbia River basin.

C. Performance of a Flat Panel Resistivity Counter to Count Steelhead in Peterson Creek, Southeast 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 resistivity counter in Peterson Creek to count a small stock ($N \approx 200$) of spring steelhead from May 1 through June 7, 2007. The counts were validated by video for 11-hour sample periods daily during daylight hours. The resistivity counter classifies signatures as either fish moving upstream (U), fish moving downstream (D) or as an unknown event (E). Video validation revealed misclassification of fish moving both upstream and downstream. Upstream fish were correctly classified 46% of the time. The most common upstream error (43%) occurred when upstream fish were erroneously classified by the counter as unknown events. The other upstream errors were instances of multiple fish counted as single fish (11%). Downstream fish were correctly classified 54% of the time, and the most common errors were split between fish classified as unknown events or multiple fish being counted as one fish. We were unable to accurately estimate the kelt emigration as only 30% of the immigrant fish were accounted for in the emigrant count, despite no adult steelhead observed during a snorkel survey at the completion of the project. Fish length was not correlated with the signal size of the counter using a log transformed linear regression ($r^2 = 0.007$), thus we were unable to estimate the length of steelhead outside of the video sample. The presumptive problem appeared to be a very low water conductivity ($\bar{x}$ = 8.8 uS/cm) in Peterson Creek. To generate an abundance estimate, we used a ratio estimator ($\hat{r} = 2.10$) to expand the raw resistivity count rather than using a simple correction factor. During the 2008 field season we will be reducing the electrode spacing on the flat panels in an attempt to amplify the counter signature to eliminate these problems and improve counter function.

D. Using GPS and Handheld Computers to Monitor Steelhead Populations

Erik Suring, Dave Stewart and Mark Lewis, Oregon Department of Fish and Wildlife

Live fish and carcass counts, which are useful monitoring tools for adult salmon species, are not applicable to steelhead monitoring because steelhead spend a shorter time on spawning beds, are elusive and hard to count when not actively spawning, and often do not die where they spawn. Redd counts are a suitable proxy for steelhead abundance but add other challenges to the monitoring program. As steelhead spawn timing is protracted, and fish may excavate multiple redds, a single redd count may be insufficient. However, because of highly variable redd longevity individual redds should be marked to avoid double counting. The Oregon Department of Fish and Wildlife's coastal adult steelhead monitoring program is entering its second year of using GPS and handheld computers to track individual redds on spawning grounds. The technology greatly reduces data entry and gives near real-time access to survey data. It augments, but does not yet replace, traditional redd marking techniques such as flagging and placing painted rocks.

E. Population-of-Origin Assignments for Winter-run Steelhead Captured as By-catch in the Columbia River Tangle-Net Fishery

Todd W. Kassler and Cheryl A. Dean, Washington Department of Fish and Wildlife

Columbia River winter-run steelhead (*Oncorhynchus mykiss*) are captured as by-catch during the lower Columbia spring Chinook tangle-net fishery. These steelhead likely come from one of these defined areas in the Columbia River: SW Coast, lower Columbia River ESU, middle Columbia River ESU and upper Willamette River ESU. Because individual steelhead cannot be morphologically identified to an ESU, we used genetic analysis to determine the population-of-origin for individuals captured in the fishery. Sixteen microsatellite markers were used to examine genetic differentiation among a total of 21 baseline collections of steelhead from the defined areas. Analysis of the 21 collections revealed that the collections were genetically distinct; however we could not assign individual fish to population-of-origin with confidence. Steelhead collections were therefore aggregated into the defined areas and assignments recalculated. The majority of steelhead that assigned from the 2005 and 2006 tangle net fisheries (N = 48 and 21 respectively) was to the lower Columbia River ESU and the upper Willamette River ESU. Impacts to the four defined areas can now be evaluated using the results of these population-of-origin assignments of steelhead in the Columbia River.

F. Using Habitat Conditions to Formulate the Parameters of a Density-Dependent Stock-Recruitment Function

Lucy Flynn, Washington Department of Fish and Wildlife

We are currently developing a steelhead population dynamics model using (*i*) a Beverton-Holt stock-recruitment function disaggregated over multiple life-history stages and (*ii*) a bioenergetics model tracking somatic growth as fish move through those life-history stages. We treat the productivity and capacity parameters of the Beverton-Holt function and the variable parameters of the bioenergetics model as functions of habitat conditions. The functional forms and parameters of those relationships are developed from the literature on *Oncorhynchus mykiss*, and treated as fixed in the modeling process. I will present the collection of relationships developed, and comment on their relative influence on total population dynamics.

G. Video: The Spawning Behavior of *O. mykiss*

John McMillan, Oregon State University

Video: The Spawning Behavior of *O. mykiss*.

H. Genetic Stock Identification (GSI) of Columbia River Basin Steelhead Using a Standardized Microsatellite Baseline

Melanie Paquin, John E. Hess, Ewann Berntson and Paul Moran, NOAA Fisheries/Northwest Fisheries Science Center

A multi-agency collaboration including WDFW, CRITFC, and NWFSC is currently underway to standardize a genetic baseline dataset (microsatellite loci) for populations of ESA-listed steelhead in the Columbia River Basin. This genetic baseline will be used for management applications including genetic stock identification (GSI) of mixed fishery catches and detection of hatchery strays. This study describes two goals related to our efforts to hone the functionality of the baseline. First, we evaluate two hierarchical spatial levels of reporting groups in terms of their ability to correctly assign individuals back to their reporting group of origin. Second, we demonstrate the use of this baseline by conducting GSI with a group of marked and unmarked steelhead returning to the Wallowa hatchery. We analyzed a preliminary baseline genotyped for 6,503 steelhead representing 120 populations using fourteen microsatellite loci. The populations were categorized into two predefined hierarchical spatial levels: 46 demographically independent populations (DIPs) nested within 4 distinct population segments (DPSs) formerly known as ESUs. As an example of a GSI application, we provided Wallowa hatchery managers with information on the probable source of unmarked fish returning to the hatchery. Our results show that just a small fraction of unmarked fish (11%) was likely to have originated from natural spawning DIPs.

I. The Effects of Long-term Hatchery Releases on Snake River Basin Steelhead Populations

Melanie M. Paquin NOAA Fisheries/Northwest Fisheries Science Center

This study compares the genetic variation among two groups of Snake River Basin steelhead populations: those with little or no hatchery influence (wild), and those with varying levels of influence from hatchery fish (naturally-produced). Wild and naturally-produced populations were used to test the hypothesis that introgression by steelhead hatchery fish has altered the naturally occurring genetic variation among Snake River Basin steelhead populations. Fifty-one steelhead populations from throughout three Snake River sub-basins, the Lower Snake, Clearwater, and Salmon Rivers, were analyzed. Analysis of 14 microsatellite loci was used to estimate levels of gene flow and to identify geographic areas that contain genetically differentiated populations. Regression analyses were performed between genetic and geographic distance using fixation index (F_{ST}) pairwise comparisons and river Km distance. These analyses show overall genetic variation is low within the Lower Snake River Sub-basin relative to the other two sub-basins. More importantly, patterns of genetic variation between the two population categories, wild and naturally-produced, within sub-basins were similar. This suggests that hatchery introgression, especially from non-indigenous hatchery sources, has not dramatically influenced the genetic structure of the Snake River steelhead populations. The results reported here are consistent with recent studies of reproductive success in hatchery-origin steelhead that suggest that non-indigenous or highly domesticated stocks may have relatively little success reproducing in the wild.

VI. Idaho Steelhead

<u>A. Steelhead Genetic Diversity at Multiple Spatial Scales in the Snake River, Idaho</u>

Alan Byrne, Idaho Department of Fish and Game

We investigated the genetic diversity of steelhead (*Oncorhynchus mykiss*) in 74 wild populations and five hatchery stocks in Idaho's Snake River Basin at the drainage, watershed, and population spatial scales using 11 microsatellite loci. We found that genetic diversity exists at multiple spatial scales. AMOVA showed genetic diversity was greater among watersheds within drainages (3.66%) than among drainages (1.97%). Over 94% of the genetic diversity found in the Clearwater, Salmon and Snake drainages was found within individual populations. The Middle Fork Salmon, South Fork Salmon, Lochsa and Selway rivers, watersheds managed for wild fish, formed distinct groups in our consensus neighbor joining (NJ) trees. At the watershed scale our analyses support differentiation of all hatchery and wild stocks. However, this was not the case for analyses at the population scale, where some populations (both wild and hatchery) were not different from others. The distribution of genetic diversity across the landscape does not appear to be organized by the A-run or B-run designations used in the management of Idaho's steelhead. The Dworshak hatchery stock was significantly different from all populations in pairwise F_{ST} comparisons and grouped with other Clearwater drainage populations in our NJ trees. The Oxbow, Sawtooth and Pahsimeroi hatcheries were indistinguishable from each other based on F_{ST} analysis. This study represents the most comprehensive genetic evaluation of Idaho's anadromous *O. mykiss* populations to date.

<u>B. Parr and Smolt Yield, Migration Timing, and Age Structure in a Wild Steelhead Population, Fish Creek, Idaho</u>

Alan Byrne, Idaho Department of Fish and Game

I estimated the number of migrants and smolts produced per female spawner from brood years (BY) 1996 to 2003. During this period the number of female spawners ranged from 26 to 251 fish. The median number of migrants leaving the stream was 459 fish per female spawner and ranged from 149 to 1,207 per female spawner. The majority of migrants leave Fish Creek in September and October. Most migrants over-winter in the mainstem Lochsa or Clearwater rivers and become smolts the following spring. However, about 5% of the fall migrants become smolts after spending an additional summer rearing in freshwater. Most of the fall migrants were age-1 or age-2 (age-2 and age-3 smolts) with a small percentage (generally less than 5%) that were age-3. The proportion of each age class was not consistent for each BY. For example, age-1 fall migrants ranged from 24% to 66% of the parr yield during the study period. Survival from fall migrant to smolt ranged from 32% to 65%.

VII. Steelhead Life History, Biology and Modeling

Session Chair: Lucy Flynn, Washington Department of Fish and Wildlife

A. A Review of Quantitative Genetic Components of Fitness in Salmonids: Implications for Adaptations to Future Change

Todd Seamons, School of Aquatic and Fishery Sciences, University of Washington; Stephanie Carlson, Department of Applied Mathematics and Statistics, University of California

Salmon, trout and charr are commonly subjected to strong, novel selective pressures due to anthropogenic disturbances and global climate change. Consequently, there is considerable interest in predicting the evolutionary trajectories of extant populations. Integral to making predictions is knowledge of the genetic architecture of fitness traits. We reviewed the published literature for estimates of heritability and genetic correlation for fitness traits in salmonine fishes with two broad goals in mind: summarization of published data and testing for differences among various important factors. Balanced coverage of the suite of factors was lacking as were estimates of some specific important factors and fitness traits. Most notably, estimates for wild populations and behavioral traits were nearly absent. Heritability estimates were skewed toward low values and genetic correlations toward large, positive values, suggesting that significant potential for evolution of traits exists. Furthermore, experimental setting had a direct effect on h^2 estimates, and other factors had more complex effects on h^2 and r_G estimates, suggesting that available estimates may be insufficient for use in models to predict evolutionary change in wild populations. Given this and other inherent complicating factors, making accurate predictions of the evolutionary trajectories of salmonine fishes will be a difficult task.

B. Life History Differentiation in Alaskan Steelhead and the Consequences of Inbreeding and Outbreeding

Jeff Hard, NOAA Fisheries; Frank Thrower, Alaska Fisheries Science Center

For two populations of Alaskan steelhead (*Oncorhynchus mykiss*) of common ancestry we evaluated inbreeding and outbreeding depression in second-generation descendants of wild fish derived from the same wild anadromous Alaskan stock in the 1920s. We measured phenotypes for growth, smoltification, and maturation in over 6,500 age-2 fish in 75 purebred and crossbred families. Smolting and precocious male maturity were highly variable among families within each population and significantly different between the populations. Genetic divergence of the populations was modest at both neutral loci and quantitative traits and appears to reflect primarily additive genetic effects and interactions among alleles within loci. However, marine survival to adulthood of progeny of resident parents released to the ocean was significantly lower than that of progeny of anadromous parents. Evidently, even low levels of adaptive differentiation can yield detectable outbreeding depression for survival in the wild.

Both populations also exhibited inbreeding depression after a single event of close inbreeding. We compared offspring of full siblings to those of randomly mated controls within each population to determine if inbreeding has significant effects on survival and growth in captivity or the wild. In captivity, survival and size were highly variable within and among five broods during protective freshwater culture with no evident trends. However, in the wild marine environment, although significant differences between inbred and control lines in size of returning adults, egg size, egg number and total egg mass after two or three years at liberty in the ocean were relatively rare, most pairwise comparisons were consistent with inbreeding depression. More importantly, survival of marked smolts to adulthood in the wild marine environment was consistently and significantly lower in both inbred lines.

The results have at least two important implications. First, disruption of “modest” local adaptations can impart significant fitness consequences for wild fish that undertake marine migrations. Second, natural selection in the wild substantially increases the amount of inbreeding depression detected, and inbreeding effects on survival and growth in captivity can be poor indicators of survival and growth in the wild.

C. Heritability of Run-Timing and Adult Size in Kalama Summer Steelhead

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

We used a microsatellite-DNA based analysis to define the pedigrees of adult offspring of summer-run steelhead spawned at the Kalama Falls Hatchery (SW Washington). The steelhead were spawned in 1999 and the offspring returned as 1-salt, 2-salt and 3-salt adults in 2001, 2002, and 2003, respectively. We collected life-history data (adult size [Fork Length: FL] and date of return) from the parents and their offspring and performed a series of offspring-parent regressions to directly estimate heritability (h^2) of the life history traits.

Estimates of h^2 were high for both traits ranging from 31 to 41% for adult size (depending on details of the particular analyses; Figures 1 and 2) and 85% for date of return (Figure 3). Interestingly, while adult size of offspring was positively correlated with the size of their parents overall, the size of offspring returning as 1-salts tended to be negatively correlated to the size of their parents. We speculate that larger, faster growing offspring that would have returned as jacks (male 1-salts) may have adopted residency as precociously maturing males and thus were underrepresented in the anadromous cohort.

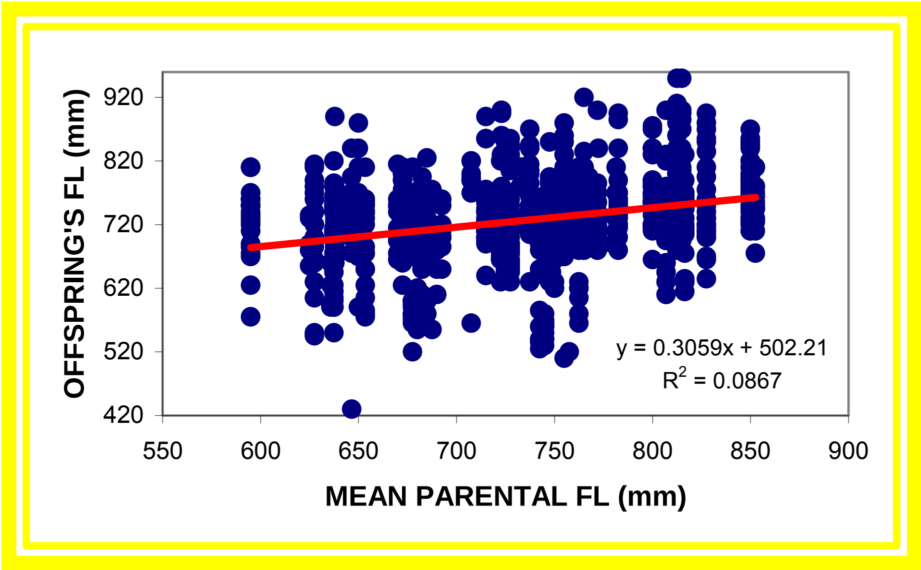

Figure 1. Regression of offspring FL on mean-parental FL.

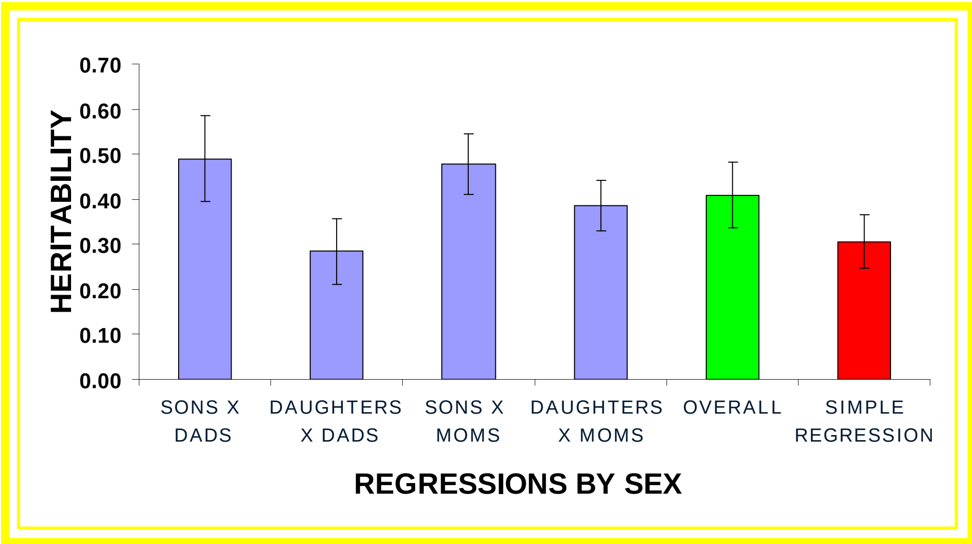

Figure 2. Heritability of adult FL with heritabilities calculated separately for each sex to account for significant differences in variance in FL between sexes (Levene's Test: P < 0.001). Overall heritability is 41%.

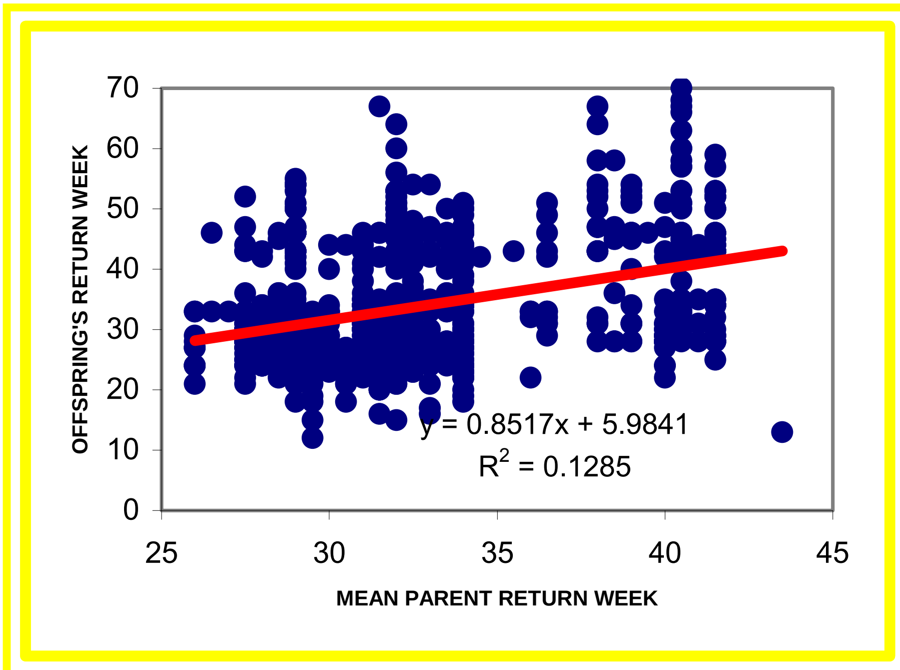

Figure 3. Regression of offspring return date on mean-parental return date.

<u>D. Observational Evidence of Spatial and Temporal Structure in a Sympatric Anadromous (Winter Steelhead) and Resident *Oncorhynchus mykiss* Mating System on the Olympic Peninsula, Washington State</u>

John McMillan, Oregon State University; Stephen Katz and George Pess, Northwest Fisheries Science Center

We documented the spawning distribution and male mating tactics of sympatric anadromous (winter steelhead) and resident *Oncorhynchus mykiss* in the Calawah and Sol Duc River basins, Washington State. Snorkel surveys and in situ behavioral observations were used to determine the spatial and temporal distribution patterns and male mating tactics of *O. mykiss* across the spawning season. In general, male steelhead entered our survey reaches earlier than female steelhead, and both entered earlier than wild resident and hatchery residual forms. Spatially, wild resident *O. mykiss* represented the greatest proportion of the population composition in the middle and upper survey reaches. Those differences coincided with mostly male and female steelhead participating in mating attempts early in the spawning season and mostly female steelhead and wild resident males at the end. Most attempted matings we observed involved a single female and single male steelhead, but attempts commonly included multiple male steelhead and/or wild resident males with their behavioral tactics differing between forms. The patterns suggest a strong temporal structure, and lesser spatial structure, to the distribution of *O. mykiss* during the spawning season, which has important implications for future studies on this complex species.

E. Movement of Resident Trout Transplanted Below a Barrier to Anadromy

Peggy Wilzbach, U.S. Geological Survey, California Cooperative Fish Research, Humboldt State University

We conducted a transplantation experiment to determine if resident rainbow trout (*O. mykiss*) isolated above a barrier to anadromy would exhibit migratory behavior when relocated below the barrier. A total sample of 150 trout (>100 mm FL) upstream of a 5 m high waterfall in Freshwater Creek was captured during fall 2005 and summer 2006 and individually marked with PIT tags. At each sampling event, half of the sample was transplanted below the waterfall, approximately 10 km from tidewater, and an equal number of tagged individuals were released above the barrier. Tagged individuals in above- and below- barrier reaches were subsequently relocated and/or recaptured to compare growth rates and movement. Movement varied considerably among individuals. The majority of transplanted individuals displayed little movement or moved in an upstream direction only; 20% moved more than 5 km downstream, and of these, half moved into tidewater and displayed morphological changes associated with smolting. Six percent of tagged, above-barrier individuals were found in below-barrier reaches, presumably washing over the falls. The smoltification of at least some transplanted individuals, coupled with above-barrier ‘leakage’ of fish downstream, suggests the potential for resident trout to exhibit migratory behavior and to enter breeding populations of steelhead.

F. Supplementation Using Steelhead Fry: Performance, Interactions with Natural Steelhead and Effect of Enriched Hatchery Rearing Environments

Chris Tatara, Julie Scheurer and Barry Berejikian, NOAA/Northwest Fisheries Science Center; Stephen Riley, U.S. Geological Survey

The role of hatcheries in steelhead management is changing. In addition to providing fish for recreational angling and harvest, hatcheries are producing fish for use in conserving, rebuilding, and recovery of natural populations. However, there is concern about the use of hatchery fish in conservation programs, especially their impact on natural populations. Implementation of conservation principles (and hatchery reform efforts) has aimed to minimize genetic effects of hatcheries on recipient natural populations, but environmental effects of hatcheries on the behavior and development of juvenile fish remain a concern. Enrichment of the hatchery environment to mimic natural features of streams and reducing the duration of hatchery rearing by releasing steelhead as fry instead of smolts are two approaches to mitigate the environmental effects on hatchery fish. We raised steelhead fry from a common genetic stock in conventional and enriched hatchery environments and stocked them with natural steelhead fry in 12 enclosures constructed in two streams. Half of the enclosures in each stream were stocked with conventional fry and the remainder with enriched fry at initial densities of 2 hatchery fry and 0.27 natural fry per square meter. Over the course of six weeks, we measured rates of aggression and foraging, territory size, habitat use, spatial distribution, growth rate, and survival. We found no differences between natural, enriched hatchery, and conventional hatchery fry in their rates of foraging and aggression, territory size, habitat use, and average instantaneous growth rate. Conventional and enriched hatchery fry had significantly lower survival and a more clumped spatial distribution than natural fry. Natural fry fed at lower rates and exhibited aggressive displays more frequently when stocked with enriched hatchery fry. Our results indicated that both conventional and enriched hatchery environments produced natural social behaviors in steelhead released as fry, and that fry from enriched environments may have altered the foraging and aggressive behavior of natural resident fry, but did not compromise their growth or survival over a six week period. We conclude that during the period shortly after release (1) hatchery steelhead fry may grow as well but not survive as well as natural steelhead fry, (2) enriched hatchery rearing environments may not improve the post-release growth or survival of steelhead fry, (3) fry raised in enriched hatchery environments affect the growth and survival of natural fry similarly to fry reared in conventional hatchery environments, and (4) supplementation with both types of hatchery fry increased total population size relative to the initial (natural) population. Alternative supplementation strategies using hatchery steelhead fry may be a useful conservation tool for rebuilding natural populations if stocking density does not exceed habitat carrying capacity.

G. Evaluating Natural Productivity and Genetic Interaction between a Segregated Hatchery Stock and a Wild Population of Steelhead Trout (*Oncorhynchus mykiss*) in Eagle Creek, Oregon

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Hatchery propagation of steelhead trout at Eagle Creek National Fish Hatchery (ECNFH) was implemented as mitigation for loss of fishery resources in the Columbia River basin. The original ECNFH winter-run broodstock was largely derived from out-of-basin Big Creek Hatchery stock from the Lower Columbia River with a component of local natural-origin (NOR) stocks. Hatchery-origin (HAT) steelhead return to Eagle Creek from December through March, whereas NOR late-run steelhead return to spawn in Eagle Creek from February to June. This temporal distinction has been viewed as advantageous because it allows for a targeted fishery on early returning HAT steelhead. Managers have assumed few matings occur between NOR and HAT fish because of distinct spawning locations and differences in spawning time. Redd counts indicate peak spawning for NOR steelhead occurs in May while the peak spawning of HAT fish at ECNFH occurs in February. The North Fork Eagle Creek is believed to be the major spawning area for NOR fish, while natural spawning of HAT fish is thought to occur primarily in the mainstem Eagle Creek. We conducted genetic structure analyses using 16 microsatellite loci to evaluate geneflow and relative productivity among naturally spawning HAT and NOR steelhead throughout the Eagle Creek watershed during return-years 2005 and 2006. Significant population heterogeneity (F_{st} = 0.018; CI

0.012-0.025) was observed between juveniles from the ECNFH raceways and NOR juvenile groups including North Fork Eagle Creek. We examine risks associated with observed levels of geneflow between NOR and HAT groups in the wild.

H. A Life History Framework to Understand Production of Juvenile Steelhead in Freshwater Applied to the John Day River, Oregon

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Chris Jordan, NOAA Fisheries; John McMillan and Justin Mills, Oregon State University

Partial migration is a phenomenon that is common to a majority of salmon, trout, and charr. In the case of *Oncorhynchus mykiss* partial migration can occur at a variety of scales, including extensive marine migrations (anadromous "steelhead" trout) that contrast with non-migratory individuals in freshwater (resident "rainbow" trout). Due to threats and declines in populations of steelhead, this migratory life history has been listed as threatened under the U.S. Endangered Species Act. Because both life histories (rainbow and steelhead) likely interact, it is important for recovery of listed steelhead to understand factors influencing life history expression. We are attempting to describe spatial variability and potential influences of environmental, population, and individual-level factors on expression of these life histories in the John Day River, a major tributary of the middle Columbia River. In one study, we are analyzing the chemistry of the otoliths of young (age 0+, 1+) *O. mykiss* to identify individuals with steelhead maternal ancestry. This provides an indirect indication of the incidence of steelhead females across a broad array (>80) of sites in the basin. In a second study, we are examining factors that influence freshwater maturation – or expression of a presumptive "rainbow" life history at 30 intensively sampled sites. Results of this work will inform a model that will allow us to examine expression of life histories in relation to management actions that focus on modifying dynamic processes that influence anadromy, or alternatively focus on fixed locations to benefit "steelhead" habitats. These alternative strategies are based on contrasting assumptions about expression of anadromy in *O. mykiss*. Through this work, we hope to provide a robust and relevant framework for developing testable hypotheses about management and a more explicit consideration of the importance of life history expression to recovery of steelhead trout.

I. Growth Trajectories of Wild California Steelhead Parr

David Swank, Will Satterthwaite, Michael Beaks and Marc Mangel, University of California; Rob Titus, California Department of Fish and Game; Joe Merz, SP Cramer Fish Sciences, Susan Sogard, National Marine Fisheries Service

Thorpe (1987) showed that in Atlantic salmon (*Salmo salar*), juveniles have annual decision windows during which they decide whether to remain immature parr, mature as stream residents, or emigrate to the ocean. These decisions take the form of a series of comparisons between realized size and an expected size relative to a threshold. We hypothesized that steelhead (*Oncorhynchus mykiss*) follow similar decision rules for this trait, and that northern and southern California steelhead stocks should show differences in the timing of this decision based on habitat variables influencing growth rates, including stream temperature, stream flow, and prey availability. To test this hypothesis, we tagged wild steelhead parr from two Central Valley rivers and two coastal California streams, and measured individual growth rates. We monitored emigration using PIT tag antennae on the coastal streams, and are currently implanting wild smolts with acoustic transmitters in a Central Valley river. Invertebrate biomass in each stream was measured using drift nets and substrate samples. Early results show much higher food availability, faster growth, and earlier ages at smolting in Central Valley rivers compared to coastal streams. PIT tag recaptures from coastal streams show that individual steelhead parr can have little to no growth from spring through fall but still emigrate the following spring.

J. Life History Pathways in *O. mykiss*: insights from Stochastic Dynamic Programming Models

Will Satterthwaite, University of California, Santa Cruz

I will discuss efforts to date attempting to apply a dynamic state variable modeling approach to predict patterns in the size and age at smolting and/or maturity for steelhead in central California. I will compare and contrast predictions for small streams on the central coast and larger rivers in the central valley. I will summarize data inputs needed for the models and predictions generated to date, then compare model behavior with that observed in the field. The model is highly successful at predicting ages at emigration in both systems, and its predicted size thresholds appear largely supported as well. I will conclude by discussing possible uses of the model framework in predicting the effects of future changes in environmental conditions on the realized life histories of steelhead in these systems.

K. Ocean Distribution and Habitat of North American Steelhead Trout

Nancy Davis, School of Aquatic and Fishery Sciences, University of Washington

Recoveries of high-seas disk tags in North American freshwater areas and recoveries of coded-wire tags (CWT) at sea provide evidence of the ocean distribution of North American steelhead trout. In this pilot study, my goal was to delineate North American steelhead ocean distribution by seasonal race, geographical region, and distinct population segment (DPS) using ocean and freshwater recapture locations. A second goal was to investigate whether observed patterns of steelhead ocean distribution could be related to sea surface temperature and to speculate how ocean warming could affect steelhead ocean distribution. Data showed that recovery efforts are limited in the western Gulf of Alaska and most ocean recoveries are restricted to the summer season. However, results suggest young fish and those originating from Oregon and California are distributed in the Gulf of Alaska, while older fish and those originating from stocks further north are distributed widely across the North Pacific. In summer, North American steelhead are not randomly distributed in the ocean with respect to sea surface temperature. They seem to have a preferred temperature range of 8-14°C.

The ocean surface area (km^2) of steelhead preferred temperatures increased from 1960s to 1980s and been declining since that time. I speculate that under future global warming conditions, steelhead ocean distribution may move northwards to cooler temperatures, resulting in a decrease in abundance along the southern edge of their freshwater distribution.

L. Assessing the Impact of Climate Change on Steelhead Viability Based on a Newly Found Linkage between Mountain Snowpack and Recruitment Performance

Mark Chilcote, Oregon Department of Fish and Wildlife

I fit recruitment data for 26 populations of steelhead in Oregon to a variety of recruitment models based on the Beverton-Holt function. I found that in its traditional form the Beverton-Holt model poorly described variations in recruitment, with only 3 of the 26 population data sets having fits that were statistically significant. However, I found that improvements in model performance occurred when any of the four environmental indices were included as an additional model variable: PDO (Pacific Decal Oscillation), PNI (Pacific Northwest Index), CRF (Columbia River Flow), and CRSI (Crater Lake and Mount Rainier Snow Index). CRSI is a new index and described here for the first time. I found that among these environment variables, the CRF and CRSI provided the most model improvement. In comparing AICc scores for each population data set, I found that for 19 of the 26 populations the CRSI was the best model. I concluded that the CRSI was a good index to use in modeling steelhead recruitment performance and might serve as a possible linkage to the effects of climate change given the prediction of declining snowpack with global warming. To explore the implications of this possible linkage I performed a population viability analysis for each population under three possible climate change scenarios of declining Cascade mountain snowpack. I found that for nearly all populations the risk of extinction increased substantially as the rate of future decline in snowpack became greater. Based on existing climate change and snowpack projections and local snow survey site characteristics, I concluded the most likely rate of decline for this study's snowpack index was 24% per 100 years. Coupling this rate of likely decline with the population viability results, I concluded it is plausible that within the next 100 years climate change could cause the number of populations with 50% or greater risk of extinction to triple from 3 out 26 to 9 out of 26 and total spawner abundance to fall to one third of its historical potential.

M. Modeling life-history traits as functional responses to environmental conditions: An adaptation of the SHIRAZ model for *Oncorhynchus mykiss*

Lucy Flynn, Washington Department of Fish and Wildlife

While many approaches have been developed to model salmonid survival as a function of habitat conditions (e.g., Jager et al. 1997, Mobrand et al. 1997, Nickelson and Lawson 1998, Scheuerell et al. 2006), life-history patterns have been almost universally treated as fixed and known. *Oncorhynchus mykiss* display an unusual degree of plasticity in life-history traits including anadromy, smolt age, and ocean age, and such approaches may be inappropriate for this species. We are currently developing an adaptation of the SHIRAZ model (Sheuerell et al. 2006) for *O. mykiss*, in which both growth and survival are modeled as functions of habitat conditions, and life-history "decisions" are modeled as functions of growth.

We model survival using the Beverton-Holt stock-recruitment function disaggregated across multiple life-history stages (Moussalli and Hilborn 1986), and track fish growth using a bioenergetics model. We maintain the established approach of treating the relationships between habitat conditions and survival (i.e., Beverton-Holt parameters) as fixed values derived from literature reviews, and extend this approach to the relationships between habitat conditions and the parameters driving the bioenergetics model. We estimate (i) underlying survival parameters, and (ii) parameters used to relate growth to life-history decisions, using both data and literature values for model outputs.

VIII. Bob Hooten Sorta Memorial "I'm Your Worst Nightmare"

Session Chair: Hal Michael, Washington Department of Fish and Wildlife

A. Modeling the Upper Extent of Wild Steelhead Distribution in Washington's Lower Columbia River Tributaries Based on Field Surveys and GIS Data: A Method for Estimating Historical Spawning Distribution?

Dan Rawding, Steve VanderPloeg and Bryce Glaser, Washington Department of Fish and Wildlife

Steelhead spawning distribution is required to develop spawning ground surveys designs to estimate current abundance, assess potential losses from culverts and other barriers, prioritize barrier removal, and possibly estimate historical spawning distribution. From 2006, WDFW has conducted over 50 redd surveys in representative streams to determine the upper limit of steelhead spawning in tributaries to the Lower Columbia River. This information has been used in conjunction with GIS data such as elevation, gradient, and drainage area to develop a model to predict the upper limit of species distribution. Since most surveys targeted the upper extent of observed steelhead spawning sites without culverts, this information could be used as a surrogate for historical spawning distribution when habitat based approaches are used to estimate historical abundance. This presentation will discuss the model, results, and application to historical distribution.

B. Return Timing for Adult Winter Steelhead Based on Age

Hal Michael, Washington Department of Fish and Wildlife

It has been recognized since the 1930s that adult winter-run steelhead may return to freshwater at different times, depending on the age of the adult fish. The timing of wild adult winter steelhead returns to the Hoh River, Snow Creek, and White River in western Washington were examined to determine if there were age-based differences in return timing. There appear to be differences in return time based on the age at which fish smolted, number of years spent in the ocean, and whether the fish is a first-time or repeat spawner.

C. What is the Importance of Repeat Spawners, Including Return Timing, Spawn Timing, Differential Sex Ratio, and Fecundity? What is a Good Level of Repeat Spawners in a Population? How Do You Manage to Protect Kelts?

John McMillan, Oregon State University

Steelhead (*Oncorhynchus mykiss*) are one of several salmonid spp. that have evolved an iteroparous reproductive strategy. Iteroparity likely plays an important role in population dynamics, however, the patterns and processes associated with iteroparity are not well studied in steelhead. In this presentation I review the research on iteroparity in steelhead with a focus on synthesizing existing information and developing

hypotheses for future research. My review suggests our current understanding of steelhead iteroparity is based largely on the description of patterns, while knowledge of the mechanisms responsible for these patterns is almost completely lacking. The level of iteroparity described in steelhead populations is highly variable (0 – 79% repeat spawners). Most repeat spawners are females with the highest levels occurring in populations at latitudinal extremes and the lowest levels generally occurring in the furthest inland populations. Empirical evidence from research on steelhead and Atlantic salmon (*Salmo salar*), a species that displays a mating system similar to steelhead, and life history theory suggest iteroparity is important to individuals and populations for several reasons. Iteroparity can balance sex ratios, increase fecundity and egg size, increase lifetime reproductive success, and spread reproductive risk over multiple generations. There is also evidence that fisheries and habitat management actions may be selecting for semelparity in some iteroparous salmonid species, although it is not clear if this has occurred with steelhead. Based on this review, I suggest that research focus on: (1) identifying the selective pressures influencing iteroparity in steelhead and how those pressures, and (2) clarifying the reproductive role of iteroparous individuals in steelhead population dynamics. The results would provide key information to Tribes, governmental agencies, and private stakeholders responsible for managing steelhead and their habitat.

Keywords: iteroparity, steelhead, repeat spawning, reproductive strategies

D. Escapement Goals for Salmon and Catch and Release (Questions about Marine-derived Nutrients and C&R Fisheries to be answered in the Discussion

Hal Michael, Washington Department of Fish and Wildlife

The presence of large numbers of spawning Pacific salmon or the addition of specific fertilizers has been shown to have a dramatic affect on steelhead smolt age, smolt production, and juvenile growth. These combine to provide a higher productivity for a given stream. Necessary levels of salmon spawning have been identified.

Catch and release fisheries have been used as a tool to allow continued use of steelhead at low run numbers. Questions about the impact of C&R fisheries on steelhead productivity are put forward for the coming discussion.

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