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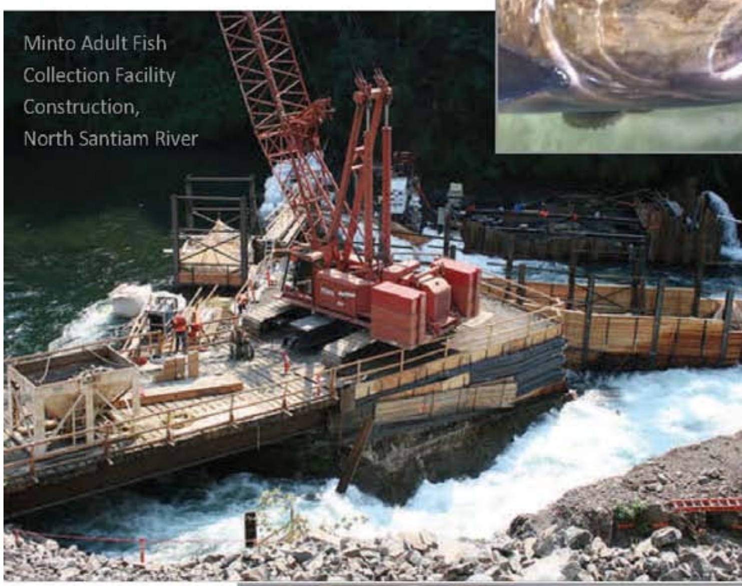
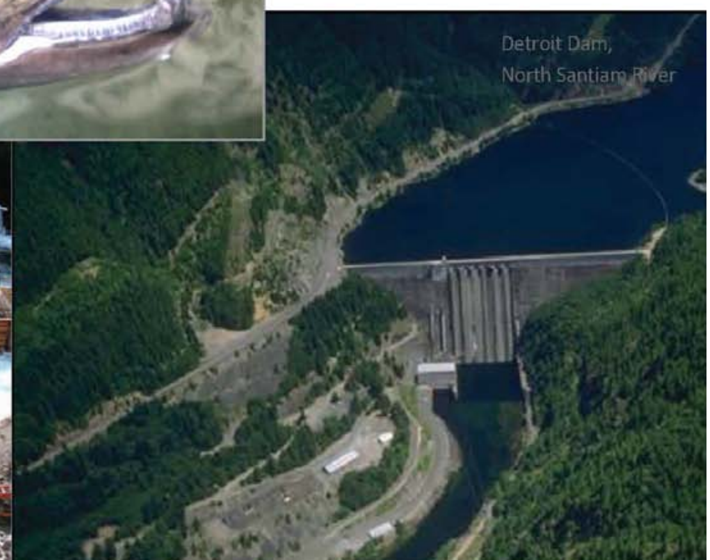
OSU
Oregon State University

2012 Willamette Basin Fisheries Science Review


Spring Chinook, South Fork McKenzie


Minto Adult Fish Collection Facility Construction, North Santiam River


Detroit Dam, North Santiam River


Spring Chinook downstream migrant, Fall Creek. Photo credit: Greg Taylor

February 5th – February 7th, 2013

LaSells Stewart Center 875 SW 26th St Corvallis, Oregon

WILLAMETTE FISHERIES SCIENCE REVIEW AGENDA

FEB 5, 2013 / DAY 1

9:00	Introduction	Rich Piaskowski, USACE
9:10	Opening Remarks	Joyce Casey, USACE
9:20	Upper Willamette River Salmon And Steelhead - Status And Limiting Factors	Rob Walton, NOAA
	BASINWIDE WATER MANAGEMENT AND WATER QUALITY	
10:00	2012 Year In Review – Dam Operations To Meet BiOp Objectives	Mary Karen Scullion & Kathryn Tackley
10:30	**BREAK (30 Min)**	
11:00	Development And Calibration Of Temperature Models For The Middle Fork Willamette And South Santiam Rivers, Oregon	Norman Buccola and Adam Stonewall
11:40	Willamette River Sustainable Rivers Project	Leslie Bach et al., TNC
12:10	**Lunch (80 Min)**	
	BASINWIDE CHINOOK & STEELHEAD STUDIES	David Griffith, USACE
1:30	The Genetic Structure Of Steelhead And Spring Chinook Salmon In The Upper Willamette River, Oregon	Marc A. Johnson and Thomas A. Friesen, ODFW
2:00	Migration Behavior And Distribution Of Adult Spring Chinook Salmon Radio-Tagged At Willamette Falls In 2012	Christopher C. Caudill, et al., UI
2:20	Migration Behavior And Distribution Of Adult Winter And Summer Steelhead Radio-Tagged At Willamette Falls In 2012	Christopher C. Caudill, et al., UI
2:40	Prespawn Mortality Of Upper Willamette River Spring Chinook Salmon: Associations With Stream Temperature, Watershed Attributes And Environmental Conditions On The Spawning Grounds.	Adrienne Roumasset and Christoper C. Caudill, UI

3:00	**BREAK (20 Min)**	
3:20	Evaluating Potential Causes And Management Of Pre-Spawning Mortality In Adult Upper Willamette River Chinook Salmon	Carl B. Schreck et al., OSU
3:50	Viable Salmonid Population (VSP) Of Willamette River Spring Chinook Populations	Rich Zabel et al., NOAA
4:10	Between The Gravel And The Sea: The Vital Role Of The Willamette River For Spring Chinook Salmon	Kirk Schroeder et al., ODFW
4:30	Characterizing Life History Patterns In UWR Chinook Salmon (Oncorhynchus Tshawytscha) Reared Above WVP Reservoirs	Sam Bourret et al., UI
4:50	Development Of Wild Fish Surrogates For Upper Willamette River Salmonids	Eric Billman, OSU
5:10	***DAY 1 Adjourned***	

FEB 6, 2013 / DAY 2

BASINWIDE CHINOOK & STEELHEAD STUDIES (Cont.)

8:30	Session Introduction	David Griffith, USACE
8:40	Conservation Genetics and the Reintroduction of Salmon Populations	Fred Allendorf, Univ of Montana

MCKENZIE RIVER SUBBASIN

9:00	Review Of Fish Return Data Collected At Cougar Fish Faciltity In The Willamette Valley, Oregon	Greg Taylor et al., USACE
9:20	2012 Hatchery Research Monitoring And Evaluation By ODFW In The Upper Willamette River - Mckenzie	Cameron Sharpe, ODFW
9:50	Lifetime Reproductive Success And The Cohort Replacement Rate For Chinook Salmon Outplanted Above Cougar Dam, South Fork Mckenzie River	Dave Jacobson et al., OSU
10:10	**BREAK (30 Min)**	
10:30	The Reproductive Success Of Hatchery And Wild Spring Chinook Released Above Cougar Dam, South Fork Mckenzie River, Oregon	Nick Sard et al., OSU
10:50	Spring Chinook Salmon Movement And Distribution In The South Fork Mckenzie River Above And Below Cougar Dam	Fred Monzyk and Jeremy Romer, ODFW
11:10	Update from an Evaluation of the Behavior of Juvenile Chinook Salmon at Cougar Reservoir and Dam: data for implementing a fish passage solution	John Beeman et al., USGS
11:40	Passage and Survival Probabilities of Juvenile Chinook Salmon at Cougar Dam and Downstream during Fall and Winter, 2012	John Beeman et al., USGS
12:00	**Lunch (80 Min)**	

MIDDLE FORK WILLAMETTE RIVER SUBBASIN

1:30	Session Introduction	Greg Taylor, USACE
1:40	Review Of Fish Return Data Collected At Fall Creek Fish Faciltiy In The Willamette Valley, Oregon	Greg Taylor et al., USACE
2:00	2012 Hatchery Research Monitoring And Evaluation By ODFW In The Upper Willamette River - Middle Fork	Cameron Sharpe, ODFW

2:20	Spawning Success Of Spring Chinook Salmon In Fall Creek And The North Fork Middle Fork Willamette River, 2008-2012	Christopher C. Caudill et al., UI
2:40	Juvenile Spring Chinook Migration In The Middle Fork Willamette River And Use Of Lookout Point Reservoir	Fred Monzyk and Jeremy Romer, ODFW
3:00	**BREAK (20 Min)**	
3:20	Outmigration Of Hatchery Spring Chinook Salmon Released Above And Below Dams In The Middle Fork Willamette River	Thomas A. Friesen et al., ODFW
3:40	Passage Behavior And Survival Of Juvenile Chinook Salmon At Fall Creek Dam, 2012	Matthew G. Nesbit et al., NOAA
4:00	The Fall Creek Drawdown: Monitoring Results From Year Two	Greg Taylor et al., USACE
4:20	Monitoring Sediment Loads And Water Quality During A Short-Term Drawdown Of Fall Creek Lake For Downstream Passage Of Juvenile Fish, Upper Willamette Basin, Oregon	L. Schenk et al., USGS
5:00	***DAY 2 Adjourned***	

FEB 7, 2013 / DAY 3

SANTIAM RIVER SUBBASIN

8:30	Session Introduction	David Leonhardt, USACE
8:40	2012 Hatchery Research Monitoring And Evaluation By ODFW In The Upper Willamette River - North Santiam	Cameron Sharpe, ODFW
9:00	Juvenile Spring Chinook Migration In The North Santiam River And Use Of Detroit Reservoir	Fred Monzyk and Jeremy Romer, ODFW
9:20	Outmigration Of Hatchery Spring Chinook Salmon Released Above And Below Dams In The North Santiam River	Thomas A. Friesen et al., ODFW
9:40	**BREAK (30 Min)**	
10:10	Hydroacoustic Evaluation Of Juvenile Salmonid Passage At Detroit Dam	Johnson et al., PNNL
10:30	Update from an Evaluation of the Behavior of Juvenile Chinook Salmon and Steelhead at Detroit Reservoir and Dam	John Beeman et al., USGS
11:00	2012 Hatchery Research Monitoring And Evaluation By ODFW In The Upper Willamette River - South Santiam	Cameron Sharpe, ODFW
11:20	Spring Chinook Salmon (Oncorhynchus Tshawytscha) And Oncorhynchus Mykiss Movement In The South Santiam River Above And Below Foster Dam	Fred Monzyk and Jeremy Romer, ODFW
11:40	Characterization Of Fish Passage Conditions Through The Fish Weir And Turbine Unit 1 At Foster Dam	JL Fulmer, Normandeau and JP Duncan, PNNL
12:00	**LUNCH (90 Min)**	
1:30	Session Introduction	Rich Piaskowski, USACE

HATCHERY DISEASE / RESIDENT FISH / ADDITIONAL TOPICS

1:40	Parasitic Copepod Infestation On Salmonid Species Rearing In Willamette Valley Reservoirs	Fred Monzyk and Jeremy Romer, ODFW
2:00	Data Collection For Assessing Mercury Loads Into And Out Of Cottage Grove Lake, Oregon, 2011 And 2012	L. Schenk et al., USGS

2:20	Macroinvertebrate Drift Density And Composition In The Upper Calapooia River, Oregon During Baseflow Conditions: Implications For Recovery Of Anadromous Salmonids	Bob Danehy et al., NCASI
2:40	Monitoring The Relative Abundance And Distribution Of Pacific Lamprey (Entosphenus Tridentatus) In The Willamette River Basin	Lance Wyss et al., OSU
3:00	**BREAK (20 Min)**	
3:30	Assessment Of Disease Outbreak Risks In Hatcheries In The Willamette River System	Jerri Bartholomew et al., OSU
4:00	Updates On Oregon Chub Recovery And Research, Including The Results Of Marking And Movement Studies	Brian L. Bangs, ODFW
4:30	Bull Trout Reintroduction Efforts In The Upper Willamette Basin – Past, Present, And Future	Nik Zymonas et al., ODFW
5:00	**MEETING Adjourned**	

UPPER WILLAMETTE RIVER SALMON AND STEELHEAD - STATUS AND LIMITING FACTORS

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There have not been significant changes in the status of the seven spring Chinook populations or the four winter steelhead populations in the last few years.

NOAA and ODFW consider five of the seven spring Chinook populations to be at very high risk of extinction and consist largely of hatchery-origin fish, with low or very low evidence of natural productivity.

NOAA Fisheries' most recent status report (2011) indicates the abundance of the four steelhead populations was is at the same levels observed in the mid-1990s when the DPS was first listed.

The Upper Willamette Recovery Plan explains: "Over the course of the last two centuries, the combined effects of fish harvest, hatchery fish interactions, flood control and hydropower operations, and habitat alterations have led to drastic declines in these populations."

We can point to progress towards recovery in several areas:

- Harvest rates, especially on naturally-produced fish, have been significantly reduced; ODFW is shifting hatchery production out of the McKenzie; research on the effects of hatcheries continues.
- Increasing restoration and protection of Willamette habitat: the International River Foundation recently awarded the 2012 Thiess International Riverprize to restoration partners in the Willamette River Basin – "Team Willamette" and the "Within Our Reach" initiative lead by MMT, OWEB, BEF, WSCs and others.
- The Corps has installed temperature control and new trap and haul facilities at Cougar Dam on the McKenzie River and a new trap-and-haul facility at Minto.
- Water operations to facilitate downstream fish passage, including Fall Creek Reservoir drawdown and testing of new operations at Cougar Dam.
- Water operations to improve natural river functions, including those recommended through the Sustainable Rivers Program.
- Research into many different uncertainties is ongoing.

With respect to research, these issues are on my unofficial list:

Regarding the effect of Dams,

- Downstream passage, including reservoir survival and fish passage alternatives and impacts to natural life history diversity.
- Effects of dams on temperature-related impairment, including pre-spawning mortality.
- Given delays in providing successful reintroduction above the dams, it is important to make progress evaluating the potential benefits and costs of significant changes in operations, such as a drawdown of LOP.
- Hatchery program effects on natural fish and reintroduction efforts, including those relating to trap operations, outplanting protocols and priorities, and fitness and competition effects (including those from hatchery origin spring Chinook, summer steelhead and trout).
- Flow management to allow for improvements in river health, including channel forming processes and seasonal inundation of accommodating areas.

Regarding the rest of the life cycle of spring Chinook and steelhead, and to track progress on limiting factors and threat reduction (not necessarily USACE responsibilities); numerous critical uncertainties remain; here are a few possible candidates for increased research,

- Survival of adults above Willamette Falls (including migration up to the spawning areas, not just 'pre-spawning mortality').
- Growth, presence/absence and survival of juveniles in the mainstem down to the Columbia and the Ocean, especially fry and sub-yearling stages.
- The long-term, sub-lethal, synergistic effect of the thousands of pollutants that are present in the Willamette.
- Improved status and trends monitoring for all Chinook and steelhead populations in the upper Willamette.
- Improved habitat status and trends monitoring to document improvements basin-wide
- The focus has been on Chinook salmon, but steelhead returns remain relatively unchanged despite the termination of winter run hatchery programs above Willamette Falls. There are numerous voids in our understanding of steelhead life history, including the role of kelts and repeat spawners, and effects of the summer steelhead and trout mitigation programs.

2012 YEAR IN REVIEW – DAM OPERATIONS TO MEET BIOP OBJECTIVES

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The Portland District Corps of Engineers owns and operates 13 dams in the Willamette Basin. The dams are operated as a system, with flood risk mitigation as their primary authorized purpose. Hydropower, navigation, irrigation, municipal and industrial water supply, recreation and flow augmentation for fish, wildlife and water quality are also authorized purposes. The Corps operates the dams under a 2008 NOAA Fisheries and USFWS Biological Opinion that includes Reasonable and Prudent Alternatives (RPAs) calling for operational and structural modifications to Corps facilities for ESA-listed fish. This discussion will provide an overview of Water Year 2012; including meteorologic conditions and river flows, modified dam operations for downstream fish passage and water quality (temperature) improvements, structural modifications to facilities, and Fall Creek bathymetric survey results.

DEVELOPMENT AND CALIBRATION OF TEMPERATURE MODELS FOR THE MIDDLE FORK WILLAMETTE AND SOUTH SANTIAM RIVERS, OREGON

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The natural thermal and hydrologic regime of the Willamette River in Oregon has been altered by the operation of dams on the river's tributaries. These changes have consequently stressed spring Chinook salmon and winter steelhead populations (both listed on the Endangered Species Act) at different life stages. In particular, autumn water temperatures in the Middle Fork Willamette River downstream of Dexter Dam can be unseasonably warm and lead to adult spawner mortality as well as early emergence or high mortality rates for incubating Chinook salmon eggs. To assist in planning for fish habitat improvement downstream of Willamette River basin dams, the U.S. Army Corps of Engineers (USACE) and its partners developed temperature models of Hills Creek, Lookout Point, and Dexter Lakes on the Middle Fork Willamette as well as Green Peter and Foster Lakes on the South Santiam River using CE-QUAL-W2, a two-dimensional hydrodynamic and water quality model. In cooperation with USACE, the U.S. Geological Survey has updated the calibration of these models to current operations using more recent and more extensive monitoring data. Additionally, a CE-QUAL-W2 temperature model was developed for the Middle Fork Willamette River between Hills Creek Dam and the head of Lookout Point Lake. The inclusion of the river model allows simulations of the entire Middle Fork Willamette River complex from Hills Creek Dam to Dexter Dam and the South Santiam complex from Foster to Green Peter Dam to assess the effects of potential operational or structural changes at each dam. Mean absolute errors for annual temperature simulations for the models range from 0.43 to 0.83°C, which is well within the acceptable level of error for the options being studied.

WILLAMETTE RIVER SUSTAINABLE RIVERS PROJECT

Leslie Bach[1], Chris Budai[2], and Keith Duffy[2]

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[2] Army Corps of Engineers

The Army Corps of Engineers (Corps) operates 13 dams in the Willamette Basin which provide a range of human benefits including flood risk management, hydropower, irrigation, and recreation. However, operation of these dams has changed the volume and timing of water flow in the river, resulting in reduced peak flows, lower spring flows, increased summer low flows, and infrequent bankfull events. Alterations to the natural flow regime affect the health and viability of the freshwater ecosystems and the aquatic and terrestrial species and communities they sustain. To address this issue, the Corps and The Nature Conservancy (the Conservancy) are working together to determine environmental flow requirements downstream of the dams, and to identify opportunities to restore key aspects of the flow regime.

The Willamette River is one of eight demonstration sites within the Sustainable Rivers Program (SRP), a national partnership between the Corps and the Conservancy aimed at developing and refining a framework for implementing environmental flows downstream of dams. The goal of the SRP is to identify opportunities to change dam operations to provide more ecologically-sustainable flows, while at the same time meeting human needs. Because the initial flow recommendations are often based on incomplete knowledge of the key flow-ecology relationships, the recommendations are implemented on a trial basis to test hypotheses and reduce uncertainties. Monitoring and adaptive management is a critical aspect of the environmental flow recommendations framework.

Initial efforts in the Willamette focused on the Middle Fork Willamette River (Middle Fork), which contains 4 of the 13 dams. Using hydrologic and ecological data, information from the literature, and expert knowledge, a set of environmental flow recommendations were identified (Gregory et al., 2007). These recommendations include flow releases in different seasons to meet different biological and ecological needs (Figure 1). The Corps implemented initial environmental flow releases on the Middle Fork from 2008-present to evaluate and test the process. An example of environmental flow implementation for water year 2012 is shown in Figure 2.

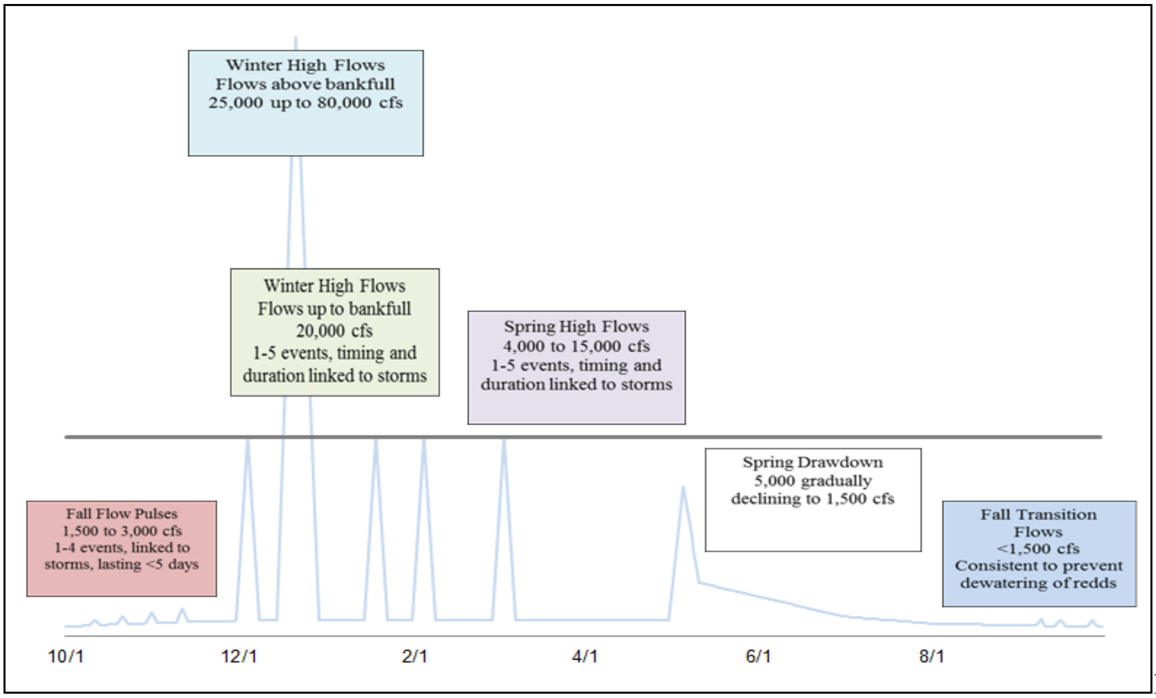

Figure 1. Recommended flows for the Middle Fork Willamette River below Dexter and Lookout Point Dams. The thick black line indicates bankfull flow.

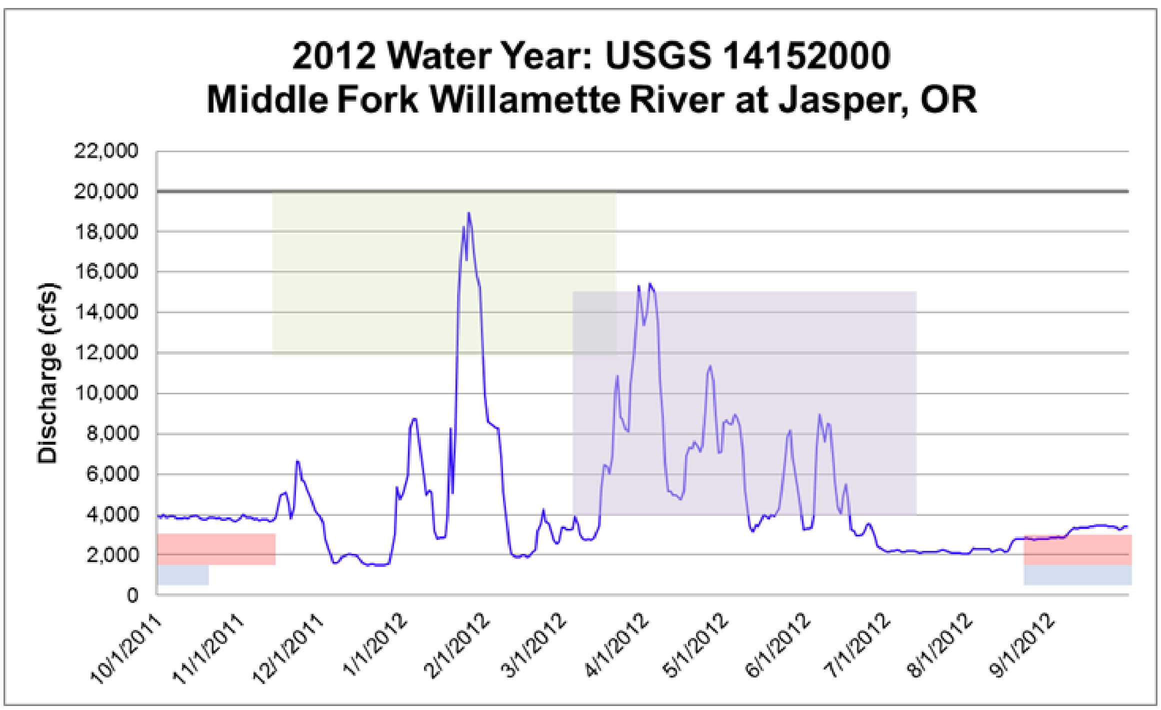

Figure 2. Streamflow in the Middle Fork Willamette River below Dexter and Lookout Point Dams for Water Year 2012. Colored boxes correspond to the recommended environmental flows in Figure 1. The location where the hydrograph overlaps with the colored boxes show where flows met environmental flow recommendations.

The adaptive management program for the Middle Fork includes a monitoring plan that evaluates both physical and biological benefits of the flow releases. Examples of physical components include extent of floodplain inundation during high flow releases; changes in length and extent of side channels and gravel bars; distribution and movement of large wood; and water temperature conditions. Biological components include indicators for determining successful recruitment and survival of riparian vegetation, particularly cottonwoods, and improvements in spawning and rearing conditions for ESA-listed salmonids and other species. A report summarizing suggested geomorphic indicators and methods was developed by University of Oregon (McDowell et al., 2012), and this information will be incorporated into the final Middle Fork monitoring plan, which will be available in April 2013.

Implementation of the monitoring plan began in 2010, and will be continued and expanded over the next several years. Preliminary results indicate that the environmental flow releases are providing ecological benefits. For example, data from a series of water level recorders installed along the river and floodplain are documenting side channel and floodplain connectivity during environmental flow releases. A study by the University of Oregon evaluating channel changes between 2005 (pre-implementation) and 2011 is showing significant changes in channel geomorphic features such as gravel bars and islands. (McDowell et al, in preparation).

In 2010 the Conservancy and the Corps completed environmental flow recommendations for the McKenzie River (Risley et al., 2010). To date, no initial releases have occurred, but a monitoring program is under development. In 2012, the Conservancy and the Corps completed an environmental flow recommendations workshop for the North and South Santiam rivers (Bach et al., in preparation).

With the completion of environmental flow recommendations for all of the major regulated tributaries, the next step is to evaluate and expand environmental flow implementation system-wide. To inform that effort, the Corps is utilizing their reservior simulation model, HEC-ResSim, to evaluate location and timing of environmental flow releases and analyze the potential effects on downstream conditions and other project purposes. The goal of the ResSim modeling is to identify the range of opportunities for achieving environmental flows. The modeling work will be completed in 2013, with the expectation that further environmental flow implementation will follow.

References:

Stan Gregory, Linda Ashkenas, Chris Nygaard, 2007. Summary Report Environmental Flows Workshop for the Middle Fork and Coast Fork of the Willamette River, Oregon. Oregon State University

John Risley, Leslie Bach, J. Rose Wallick, 2010. Environmental Flow Recommendations Workshop for the McKenzie River, Oregon. The Nature Conservancy.

Leslie Bach, Jason Nuckols and Emilie Blevins, 2013. Summary Report: Environmental Flows Workshop for the Santiam River Basin, Oregon. The Nature Conservancy (in preparation).

Patricia F. McDowell, W. Andrew Marcus and Suzanne Walther, 2012. Willamette Sustainable River Project Phase 1: Development of a monitoring plan for environmental flow recommendations on the Middle Fork Willamette River, Oregon. University of Oregon.

Patricia F. McDowell and James Dietrich, 2013. Willamette Sustainable River Project Phase 2: Development of a monitoring plan for environmental flow recommendations on the Middle Fork Willamette River, Oregon. University of Oregon.

THE GENETIC STRUCTURE OF STEELHEAD AND SPRING CHINOOK SALMON IN THE UPPER WILLAMETTE RIVER, OREGON

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Molecular genetic data can provide unique insights to the structure, diversity and integrity of managed fish populations. In the upper Willamette River, Oregon, state operated hatcheries produce spring Chinook salmon (*Oncorhynchus tshawytscha*) and summer steelhead (*O. mykiss*) to mitigate for habitat losses caused by Willamette Project dams and to provide harvest opportunities for sport and commercial fisheries. Whereas spring Chinook salmon and winter steelhead are native to the basin, summer steelhead are not.

Using a suite of 17 microsatellite markers, we characterized wild and hatchery populations of spring Chinook salmon from major tributaries of the Willamette River. Our data suggest that weak but statistically significant genetic structure exists among spring Chinook populations from different Willamette River subbasins. We found little or no evidence for genetic structure between hatchery and wild populations within subbasins, though hatchery populations tended to present higher mean heterozygosities (81-82%) than local wild populations (62-79%). Among Willamette River populations, we found no evidence for selection on the markers examined, including four immune-relevant loci. We used our data to perform forward-time simulations that explored relationships between various migration rates with θ, heterozygosity and total allele count. Simulation results suggested that symmetrical migration rates of 5% and 10% could maintain similar levels of population genetic diversity and structure. In a similar study, an analysis of microsatellite data suggested that Willamette River *O. mykiss* are represented by four major clades: resident rainbow trout, east-side tributary winter steelhead, west-side tributary winter steelhead, and summer steelhead. Using genetic stock identification of juvenile *O. mykiss* sampled at Willamette Falls in 2009-2011, we found that 10.5% of unmarked (natural origin) fish assigned as summer steelhead. Subsequent analyses of samples collected within Willamette River subbasins found little or no evidence for natural production of summer steelhead in the North and South Santiam rivers (only 1 of 63 samples assigned as summer steelhead), in contrast with strong evidence for substantial natural production of summer steelhead in the McKenzie River (71% of samples assigned as summer steelhead). However, when analyzed with the Bayesian clustering software STRUCTURE, samples from all locations provided evidence of hybridization between summer steelhead and east-side tributary winter steelhead (9-15% of juvenile samples).

Recovery goals for Chinook salmon in the upper Willamette River are subbasin-specific. We demonstrated that significant population genetic structure exists among subbasins, suggesting that subbasin-level management is a sound approach to overall recovery of the ESU, and that previous assertions of population homogeneity are inaccurate. We also confirmed that natural production of summer steelhead occurs in the basin and that some level of genetic introgression with native winter steelhead occurs. While the levels of natural production by and introgression with summer steelhead appear to be low within the winter steelhead DPS, it remains to be determined by managers what level of risk is acceptable. Genetic information for both steelhead and Chinook will likely be valuable for reintroduction planning.

MIGRATION BEHAVIOR AND DISTRIBUTION OF ADULT SPRING CHINOOK SALMON RADIO-TAGGED AT WILLAMETTE FALLS IN 2012

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Our objectives were to describe the migration behavior and spawning distributions of adult spring Chinook salmon radio tagged at Willamette Falls Dam in 2012, including both unclipped (presumed wild origin) and clipped (presumed hatchery origin) adults. We also evaluated the effects of two handling treatments on the behavior of tagged salmon: a eugenol-based anesthetic and a fish restraint device (FRD) modeled after Larson (1995). Tagging was conducted collaboratively with Eugene Water and Electric Board (EWEB) and their contractor, Normandeau Associates. The EWEB-Normandeau study monitored Chinook salmon with unclipped adipose fins in the McKenzie River at the Leaburg-Walterville complex as part of the Projects' re-licensing requirements. The results of the EWEB-Normandeau study will be presented at a future forum. Conditions during the 2012 migration season were characterized by cool temperatures and high flows, similar to conditions in our 2011 study.

We radio tagged 500 Chinook salmon through 2 July, which represented 1.4% of the adult Chinook salmon counted at the dam from 1 April through 31 July. Our sample was weighted toward unclipped adults in an effort to meet EWEB-Normandeau study goals, comprising 62% of our sample ($N_{unclipped}$ = 311). The percentage of unclipped salmon in the run-at-large estimated to have passed Willamette Falls based on ODFW fish counts was ~23%. One hundred fifty-four (~50%) unclipped Chinook salmon were tagged using anesthetic and 157 (~50%) were tagged using the FRD treatment. All 189 Chinook salmon with clipped adipose fins received the FRD handling treatment while being radio tagged. One hundred fifty-eight (46%) of the 346 salmon tagged with the FRD treatment exited the dam after release compared to 32 (21%) of the 154 salmon tagged with anesthetic ($P<0.001$, Chi-square Test). A higher percentage of anesthetized salmon that exited the dam after release subsequently ascended the dam (44%) compared to the percentage of FRD salmon that ascended the dam after their exit from the dam (29%). Among all tagged salmon, there were 22 fallback events by 22 unique salmon and none of them subsequently re-ascended the dam.

The river section to which the highest percentage of all tagged salmon migrated was downstream from Willamette Falls (26%). Preliminary analyses suggest FRD treated adults were three times more likely to have final records below the dam compared to anesthetized salmon, potentially inflating the total number of adults with last records below the Falls. Among tributaries upstream from Willamette Falls, the Santiam (25%) and McKenzie (19%) rivers had the highest percentages of tagged salmon return to them. Nine percent of tagged salmon were last detected in the Middle Fork and 8% were last detected in the lower main stem (downstream from the Santiam River and upstream from Willamette Falls). Remaining percentages included 4% to the Clackamas River, 3% at Willamette Falls Dam, and 1% each to Fall Creek, the Molalla River, and upper main stem.

The time tagged salmon spent in the main stem Willamette River was positively related to the distance between Willamette Falls Dam and the tributary that they ultimately entered. On median, residency times were 10.9 days for salmon that returned to the Santiam River, 19.8 days for those that returned to the McKenzie River, and 21.3 days for those that returned to the Middle Fork. Median migration rates in the main stem were similar among groups returning to the Santiam, McKenzie and Middle Fork subbasins, ranging from 12.5 (McKenzie) to 12.8 (Middle Fork) river kilometers/day. Migration rates increased (and travel times decreased) later in the season and were likely associated with increased water temperatures.

The data from this study will provide valuable baseline information on the relationship between upstream migration, Willamette Valley Project operations, and environmental conditions, and we are integrating the data with results from spring Chinook salmon studies in Fall Creek and the North Fork Middle Fork Willamette River to evaluate the potential contribution of main stem versus tributary factors to pre-spawn mortality on spawning grounds. The quantitative estimates of migration rate obtained here are also being used in a series of predictive models to evaluate Chinook prespawn mortality in relation to bioenergetics, pathogen loads, migration rate, and alternative management scenarios (Colvin et al.).

References

Larson, L. L. 1995. A portable restraint cradle for handling large salmonids. North American Journal of Fisheries Management 15:654-656.

MIGRATION BEHAVIOR AND DISTRIBUTION OF ADULT WINTER AND SUMMER STEELHEAD RADIO-TAGGED AT WILLAMETTE FALLS IN 2012

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[1] Department of Fish and Wildlife Sciences, University of Idaho, Moscow, ID 83844
[2] Oregon Division of Fish and Wildlife, Corvallis Research Lab, 28655 Highway 34, Corvallis, OR 97333

Our objectives were to describe the migration behavior and spawning distributions of winter and summer steelhead returning to the Willamette River in 2012. We also evaluated the effects of two handling treatments on the behavior of tagged steelhead: a eugenol-based anesthetic versus a fish restraint device (FRD) modeled after Larson (1995).

Winter Steelhead

We radio tagged a total of 168 adult winter steelhead from 2 March through 31 May plus three unclipped steelhead deemed by the taggers to be winter-run fish after 31 May, for a total of 171 tagged winter steelhead. Approximately 49% (84/171) of the tagged steelhead received an anesthetic treatment and 51% (87/171) received the FRD treatment. Approximately 17% of winter steelhead in both treatments exited the dam after release (14/84 anesthetic treated; 15/87 of FRD treated). Two winter steelhead subsequently ascended the dam; both had received the anesthetic treatment. Among the 171 radio-tagged winter steelhead released, two (~1%) regurgitated their transmitters at the dam.

We inferred spawning distribution from the maximum upstream records for each adult. The highest percentage of tagged winter steelhead migrated to the Santiam River (37%). Eighteen percent migrated no further upstream than Willamette Falls Dam. Fourteen percent migrated to the Molalla River, 14% migrated to the Middle Fork, and less than 5% each migrated to other tributaries or river sections.

We observed substantial downstream movements by tagged steelhead potentially representing post-spawning outmigration (kelting) events. There were 65 fallback events at Willamette Falls Dam by 64 unique steelhead. Sixty-two of the 65 fallback events were associated with steelhead that had previously been detected in upstream tributaries indicating potential spawning events prior to observed downstream movements. Among the 171 winter steelhead tagged, we estimate that 78 (46%) were subsequently kelts based on their detections in tributaries upstream from the dam and their subsequent downstream movements (43 – Santiam, 16 – Molalla, 5 – Yamhill, 3 – Tualatin, 1 – Calapooia, and 10 – Middle Fork).

Summer steelhead

We radio tagged a total of 208 summer steelhead between 28 March and 1 July. Thirteen steelhead deemed by the taggers to be summer-run fish had intact adipose fins (i.e., missing clips or wild summers). All ad-clipped summer steelhead received the FRD treatment with the exception of one that was inadvertently anesthetized prior to tagging. Eighteen percent (35/194) of summer steelhead with clipped adipose fins exited the dam after release. Of the 35 ad-clipped steelhead that exited, 17 (49%) subsequently ascended the dam. Ten wild summers received the anesthetic treatment and three received the FRD treatment.

The highest percentage of all tagged summer steelhead migrated to the Santiam River (35%), followed by the McKenzie River (15%) and the Middle Fork (15%). Eleven percent of the sample was last detected downstream from Willamette Falls Dam, 8% was last detected in the lower main stem, and 6% was last detected in the upper mainstem. Five percent was last detected in the Middle Fork near the Coast Fork and smaller percentages were last detected in the Coast Fork and in Fall Creek (~1% each).

Within the unclipped “wild” summer group (*n*=13), most were last detected in the Middle Fork (5) or the McKenzie river (4). One each was last detected at Fall Creek, in the Middle Fork near the Coast Fork, at Willamette Falls Dam, or downstream from it.

Mobile tracking of radio-tagged steelhead by ODFW detected unique tags implanted in winter-run (*n* = 84) and summer-run (*n* = 91) steelhead at Willamette Falls in 464 detection events. The results revealed spatial overlap of summer and winter steelhead in the South Santiam and Middle Fork Willamette rivers. We will monitor the movements of tagged summer steelhead in the spring of 2013 to evaluate spawning distributions (e.g., if they differ from our last records collected in fall 2012) and kelting rates.

Summer steelhead trapped at Foster Dam on the South Santiam and Dexter Dam on the Middle Fork are frequently re-released (“recycled”) into the river to support recreational fisheries. We radio tagged summer steelhead trapped at both of these locations that were then recycled and continued to monitor movements. Our main objective was to track any summer steelhead that migrated downstream and assess the potential for spawning or mixing with winter steelhead the following spring.

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PRESPAWN MORTALITY OF UPPER WILLAMETTE RIVER SPRING CHINOOK SALMON: ASSOCIATIONS WITH STREAM TEMPERATURE, WATERSHED ATTRIBUTES AND ENVIRONMENTAL CONDITIONS ON THE SPAWNING GROUNDS

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Prespawn mortality (PSM) rates in UWR spring Chinook salmon vary considerably both between sub-basins within a year and between years in the same sub-basin. Annual rates ranged from 1% in the Upper McKenzie River in 2008 to 95% in the Middle Fork Willamette River in 2007. We hypothesized that environmental conditions during the holding period and population differences associated with fish density and origin, fish handling practices, and other factors can partially explain variability in PSM rates. We analyzed a dataset of PSM rates from 11 index reaches in the Willamette River and the adjacent Sandy River basin with observations from 2001-2010 using mixed model regression and Akaike Information Criterion (AIC) scores. The best model for PSM included both environmental factors that vary from year-to-year (e.g., stream temperature, spawner density) and relatively static watershed-scale features (e.g., % basin agriculture). Exploratory analyses revealed a complex and hierarchical set of relationships between PSM and predictor variables and among the predictor variables themselves (i.e., many predictors were inter-correlated). Nonetheless, consistent positive and significant associations were found between annual PSM rate and 7 day average maximum temperature (7-DAM) and fish density (D), as well as a significant negative association with percent wild (W). The associations between PSM and 7-DAM are consistent with other observations of increased PSM rates at higher stream temperatures. Additional analyses revealed 7-DAM may be largely controlled by differences among sub-basins in underlying geology and land-use. Percent wild (W) and spawner density (D) were strongly inter-correlated. Reaches with high densities were those with high numbers of hatchery fish (and hence low W) and were also in areas below dams, potentially with marginal quality spawning habitat. Thus, density dependent mechanisms may have acted to produce a negative ecological hatchery effect below dams. Further investigation of these relationships are needed to test hypotheses about underlying mechanisms and will assist with the prioritization of management action within and among sub-basins.

Given the association between PSM and temperature observed here and elsewhere, we investigated the relationships between habitat, stream temperature, fish behavior and PSM at finer scales in upper sections of the North Fork Middle Fork (NFMF) and Fall Creek. We sampled longitudinal temperatures at fine scales (~ meter scale) above adult outplant release sites on a 5.5 km reach of Fall Creek and a 9.3 km reach of the NFMF by towing a high-resolution data logger (Solinist® Levellogger®) georeferenced with a continuous GPS track. Statistical models were used to relate these temperature profiles to physical attributes of the upstream environment and explained 98% (Fall Creek) and 95% (NFMF) of fine scale variability in stream temperature, with past fire severity explaining 84% of variation in stream temperature in Fall Creek and elevation explaining 89% in the NFMF. Release site temperatures in July and August of 2009-2011 differed between Fall Creek (range: 18°C-25°C) and the NFMF (12°C-18°C). Salmon movement data for the same years also contrasted—fish were observed to move considerable distances upstream from the Fall Creek release site to cooler holding pools whereas the majority of fish in the NFMF held and spawned near the release site, which had water temperatures near values reported in the literature as preferred. Within Fall Creek, we observed aggregation in the coolest available reach, suggesting that relatively small differences in stream temperature (i.e. ~1°C) may be biologically significant when ambient temperatures approach those which limit survival (>18°C). The results of this study indicate that behavioral thermoregulation may differ among streams and is affected by factors acting at multiple scales. Knowledge of longitudinal variation in temperature can inform adult outplant programs (e.g., selection of outplant sites) and reintroduction programs by identifying thermally suitable sites and/or access to suitable sites. These methods can be used for cost-effective and widespread thermal mapping of critical aquatic habitat for salmonids and other species potentially affected by warming climate.

EVALUATING POTENTIAL CAUSES AND MANAGEMENT OF PRE-SPAWNING MORTALITY IN ADULT UPPER WILLAMETTE RIVER CHINOOK SALMON

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With prespawn mortality as high as 90%, death before spawning can negatively impact spring Chinook salmon, *Oncorhynchus tshawytscha* population sustainability in the Willamette River. The objectives of this study are to determine the cause of prespawning mortality (PSM) in outplanted spring Chinook salmon in the upper Willamette River system. We used a combination of observational and experimental study. In particular, we used standard necropsy methodologies to perform gross and histological examinations of outplanted fish from the upper North Fork of the Middle Fork of the Willamette River, Fall Creek, McKenzie River, South Santiam River, and North Santiam River. We compared fish that (1) died prespawning, (2) fish from Willamette Falls that had not experienced the system above Oregon City, (3) fish taken alive at about the same time as prespawned mortalities and those that (4) spawned in the wild, (5) those that spawned at Willamette Hatchery, and (6) fish from Willamette Falls and Dexter allowed to mature in a cool, pathogen free facility (Fish Performance and Genetics Laboratory, FPGL). We included fish representing different temporal parts of the run in the above comparisons. Results from previous years show that adults held in pathogen free, constant temperature water generally have less severe infections than those in the river. In addition, we observed higher survival to spawn in held fish, with transport stress and pathogen outbreaks being the main causes of prespawn mortality.

Two experiments were developed to address the interaction of parasites and stress. The first experiment was to determine if elevated cortisol makes salmon more susceptible to infection with *Nanophyetus salmincola.* Adult Chinook entering the Willamette have relatively low numbers of *N. salmincola*, with numbers increasing as fish travel upstream. It seems that levels of infection increase over time, but it also possible that stress (an immune-suppressant) is playing a role. Juvenile Chinook were treated with cortisol via a cocoa butter carrier and then exposed to Juga snails, *Oxytrema spp.*, infected with *N. salmincola.* Samples were taken every two weeks to determine cortisol and parasite levels. Fish were successfully infected with *N. salmincola*, and correlations with cortisol will be discussed. The second experiment was to examine the progression of *Parvicapsula minibicornis* infection, a pathogen associated with prespawn mortality of sockeye in the Fraser River. Kidney from infected adults was suspended in phosphate buffered saline and injected into 60 juveniles. Fish were sampled for histology every two weeks over a three month period. For the second study, injection of infected kidney did not successfully transmit *P. minibicornis*. Troubleshooting and possible directions will be discussed.

Even though PSM appeared to be relatively low in the Willamette system compared to previous years, we found that those fish that did die prior to spawning appeared heavily infected with parasites. Similar to previous study years, massive infections and severe lesions were identified in PSM fish. Pathogen burdens in PSM fish were consistently greater than healthy fish collected during the summer, indicating that fish of the upper Willamette system are dying with infections associated with multiple pathogens. It appears that the fish are becoming infected with parasites in migratory corridor above Willamette Falls, as judged by low prevalence of parasites in fish from below that area. However, bacterial infections that have the potential to thrive in stressed fish are already present (as determined by fish held at FPGL). In addition, conditions in the upper river, perhaps elevated temperature, likely are responsible for some heavy parasite burdens in fish maturing in the upper river system. This contention is based on the fact that fish that matured in cool, pathogen free water at the FPGL did not have such infections. In addition, there is probably an association of time in the river with PSM, since PSM fish collected mid-summer show pathogen profiles similar to post-spawned fish examined in September.

As previous observation and experimental studies suggest, spring Chinook PSM is the complex interaction of migration conditions, energetic status, pathogen burden, and stress. We have developed a simulation model to synthesize UWR spring Chinook PSM and evaluate potential management strategies. Currently the model assumes that PSM is associated with migratory corridor duration, which is a simplification of the complex biotic and abiotic interactions that result in prespawn mortality. This assumption represents a key uncertainty requiring further study. Specifically, refining the link between pathogen burden, energetics, stress, and migratory corridor exposure of prespawn mortality fish is a critical component to understanding and managing PSM. Specifically, the model simulates individual spring Chinook migrating from Willamette Falls to projects and subsequent trap and haul outplanting. The model simulates UWR spring Chinook fate (prespawn or spawning mortality) as a function of time in the system since results of ongoing and previous studies indicate that PSM is caused by an interaction of environmental factors, particularly water temperature, fish condition, pathogens, and energetic status, which are all a function of time within the Willamette River system. Available data on adult migration (e.g., radio tagging studies), trap operations (e.g., trap catch data), transport (e.g., transport mortality data) and outplant dynamics (e.g., carcass data, redd count data) from organizations working within the basin including: Oregon Department of Fish and Wildlife, University of Idaho, Oregon State University, US Army Corps of Engineers, Oregon Cooperative Fish and Wildlife Research Unit, and US Geological Survey was used to parameterize the model.

Simulation results indicate that PSM may be reduced in outplant by outplanting fish that are captured earlier in trapping operations, assuming PSM is a function of duration in the migratory corridor. Specifically, migratory corridor duration varied from ~20 days to an excess of 150 days in stochastic simulations. However, migratory corridor duration of captured fish varied over simulated trapping operations, however early run fish tended to have the shortest time spent in the migratory corridor. Typically, excess spring Chinook are outplanted once hatchery quotas are met, which potentially selects fish that have been in the system longer with a higher risk of prespawn mortality, especially since these fish tend to have higher pathogen loads. Since higher pathogen loads have been associated with PSM in outplanted fish, outplanting fish from earlier in the run may reduce PSM—assuming hatchery quotas can be met. Alternatively, simulation results indicated that hatchery holding of fish prior to outplanting may reduce PSM in outplant basins, especially if PSM levels are expected to be high.

In summary, this study has shown associations between PSM and water temperature, exposure, salmon condition, and pathogens, however, causal links remain speculative and uncertain. Current results to date have encompassed a small portion of Willamette River hydrological variability and therefore suggest that much can be learned from continued study. In fact, we have just scratched the surface regarding the prespawning mortality phenomenon and how to manage it. In particular, the effect of the low water temperatures and high flows occurring over the previous years of study limits generalization of results to years characterized by high springtime flows and low water temperature. In other words, the limited interannual hydrological variability associated with previous study years severely limits generalization of patterns. Continued assessment of the association of PMS and interannual variation in hydrologic conditions will be needed to more completely understand these dynamics.

VIABLE SALMONID POPULATION (VSP) OF WILLAMETTE RIVER SPRING CHINOOK POPULATIONS

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The Viable Salmonid Population (VSP) approach describes the performance of salmonid populations in terms of four metrics: Abundance, Productivity, Diversity, and Spatial Structure. This approach has been adopted by NOAA Fisheries to evaluate the status of evolutionarily significant units (ESUs) and their component populations for risk assessments. We applied this approach to assess the effectiveness of proposed actions for four populations of Willamette River spring Chinook salmon: the McKenzie, Middle Fork, and North and South Santiam Chinook populations. We first modified existing life-cycle models that were developed using the Species Life-cycle Analysis Modules (SLAM) model. Our primary modifications to the SLAM models were: 1) Include diversity in the juvenile life history; 2) Modify the algorithms that model the effects of hatchery spawners on wild spawners to incorporate recent information and to provide options based on separate studies; 3) Incorporate pre-spawn mortality functions that include spawner density and temperature; and 4) Incorporate a term to reflect the substantial loss of fish between Willamette Falls and spawning grounds. We then developed methods to use outputs from the SLAM model to calculate VSP parameters to determine how populations perform under a range of scenarios. To demonstrate the approach, we first conducted a sensitivity analysis to determine which mode components are most important for determining population performance. Next, to demonstrate how the tool can be used to assess a suite of proposed actions, we modeled proposed actions for juvenile passage at Cougar Dam. Finally, we will discuss future directions of the modeling, including modeling of steelhead populations and updating estuary/ocean survival relationships.

BETWEEN THE GRAVEL AND THE SEA: THE VITAL ROLE OF THE WILLAMETTE RIVER FOR SPRING CHINOOK SALMON

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Although the Willamette River has undergone remarkable recoveries in the past, the perception of the river as simplified and polluted has persisted for many decades, and has influenced how we think salmon use the river. Much work remains to address the legacy of pollution and to understand the threat of modern pollutants that are less visible and perhaps more insidious than the industrial wastes of the past. However, because the view of the Willamette River as an inhospitable environment for Chinook salmon has lingered, the river is sometimes overlooked as rearing habitat for juvenile Chinook or is seen as merely a migration corridor used by salmon to race between spawning areas and the ocean. Our research on juvenile spring Chinook salmon over the last 10 years has revealed a broad diversity of rearing and migratory life histories and has demonstrated the importance of the Willamette River to the expression of life histories. A story emerging from our studies is about the effect of past environments in shaping the diversity we see today, and how that diversity provides resilience to the upper Willamette spring Chinook salmon.

Juvenile Chinook salmon can be found in the Willamette River throughout the year and are particularly abundant in late winter through mid-summer when two year classes overlap. Some juvenile fish migrate to the Willamette River as fry shortly after emerging from the gravel in late winter; spending several months to over a year in the river before migrating to the ocean. Throughout their first spring of life, juvenile Chinook salmon continue moving into the Willamette River from spawning areas and these are followed by additional migrations of fish in the fall and in the spring of their second year. This widespread migration of juvenile salmon to the Willamette River likely developed because it allowed fish to access productive habitats created by the extensive network of braided channels that characterized the historic Willamette. Rearing seasons and rearing habitats can be greatly extended for juvenile fish that undertake long-distance migrations because the Willamette River offers diverse growing conditions across a range of environments. Juvenile spring Chinook salmon rearing in the Willamette River grow at a faster rate than those rearing in spawning tributaries.

Because juvenile Chinook rear in the Willamette River at different sizes and in different seasons, they use a wide variety of habitats that include shallow beaches at the edge of the river, and riffles and pools in the main channel. Off-channel habitats are also important for rearing, such as seasonally flooded side channels, floodplains, small intermittent streams, and even rivers that do not have spawning populations. Despite over a century of changes to the Willamette River that resulted in the loss of river channels along much of the river, many areas still provide the diverse habitats needed by young salmon. Conserving and restoring habitat diversity in the Willamette River will be an important component of recovering spring Chinook, and information about juvenile Chinook can be used to help guide decisions about restoration actions and priorities.

Although we have learned much about the diversity of life history in Willamette spring Chinook salmon, we also recognize limitations in understanding complex environmental variables that vary spatially and temporally, and ultimately affect expression of behaviors. We will never fully understand this complexity, but the varying contribution of life histories in adult returns has demonstrated the importance of diversity to population resilience. Diversity should be a critical part of recovery strategies not only in the biological sense but also in developing engineering and restoration approaches. Recovering a complex species in an uncertain environment is more likely to succeed if creative strategies are developed and diverse approaches are adopted.

CHARACTERIZING LIFE HISTORY PATTERNS IN UWR CHINOOK SALMON (*ONCORHYNCHUS TSHAWYTSCHA*) REARED ABOVE WVP RESERVOIRS

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Understanding movement behavior and habitat use in early life history stages is important for effective conservation and management of ESA-listed species. For threatened spring Chinook salmon (*Oncorhynchus tshawytscha*) of the Willamette River, quantifying freshwater habitat use can identify habitat and dam passage improvements that will assist in management strategies. Currently, in the Willamette river, offspring of ESA-listed adult Chinook salmon outplanted above project reservoirs may rear near outplant sites in natal spawning streams (natal tributaries), in reservoirs below natal tributaries, in the mainstem and lower Willamette River, and/or in the freshwater Columbia River Estuary prior to saltwater entry. We sampled isotopic ratio $^{87}Sr/^{86}Sr$ and natural elemental tracers (Sr, Ba, Mg, Mn, and Ca) from water samples and otoliths in Chinook salmon juveniles and adults collected from rearing and spawning habitats, respectively, to address questions of movement, freshwater habitat use, and life history characteristics at multiple spatial scales within the Willamette Basin. Counter to expectations, we found that variation in otolith microchemistry was able to resolve several life history attributes at the finest scale (within headwater basin) and largest spatial scales (freshwater vs. marine), but had little resolving power at intermediate scales (among headwater basins or between headwaters and the mainstem Willamette River). Elemental tracers showed similar trends in water and otolith samples and were used to estimate first year rearing habitat in juvenile Chinook salmon. Our results suggest that 90% of adults reared in Lookout Point reservoir and 10% reared in the upstream natal stream habitat. There was little evidence of extensive lower Columbia River use in analyzed samples, though important uncertainties remain.
In addition to identifying rearing habitat, we were also interested in using information from scales and otoliths to quantify additional life history traits and the composition of life history types in samples of returning adults. Recent analyses of screw trap data suggest that juvenile Chinook salmon life history strategies are variable within and among Willamette Valley populations, including traits that resemble both an ocean-type life history with subyearling emigration in summer or fall and a stream-type life history with yearling emigration the following spring. Otolith isotope and elemental ratios $^{87}Sr/^{86}Sr$ and Sr:Ca combined with otolith structural patterns were used to characterize juvenile life histories, estimate juvenile size and age at freshwater emigration, and assess relative growth between natal rearing habitats. We also used scale morphometric patterns, to discern juvenile habitat use and age at freshwater emigration. We found that a significant portion of juvenile Chinook salmon reared in project reservoirs and emigrates from freshwater at large sizes, which may be provide a survival advantage to adulthood. Otolith microstructure analysis suggested increased growth in project reservoirs relative to natal rearing streams. We found a high correspondence between scale juvenile life history assignment and otolith chemical life history assignment, which suggests accurate scale life history depiction. In adult samples, reservoir life history type was inferred for the majority of individuals in both subyearling and yearling outmigrant classes. These methods should help resolve the relative fitness of different life history pathways and assist in identifying effective management strategies during implementation of the WVP Biological Opinion.

DEVELOPMENT OF WILD FISH SURROGATES FOR UPPER WILLAMETTE RIVER SALMONIDS

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Willamette Valley Project Research, Monitoring, and Evaluation (RM&E) studies use various tagging methodologies to assess the movement behavior and survival of juvenile salmonids as a consequence of hydroelectric projects. Use of run-of-the-river juveniles for these studies presents two challenges: 1) ability to capture sufficient individuals for adequate sample sizes within the narrow time frame for these studies, and 2) potential for unacceptable levels of take on ESA-listed populations due to handling stress. To overcome these challenges, RM&E studies have used hatchery-origin juveniles to accommodate sample sizes required for robust tagging studies. The goal of this project is to assess the potential to use targeted rearing techniques to produce juvenile Chinook salmon, *Oncorhynchus tshawytscha*, from hatchery stocks that exhibit desired phenotypes of naturally-reared fish. This project also provides an opportunity to understand the factors that drive the expression of early life history phenotypes, essential information necessary to achieve recovery goals for these species. This project is not intended to reform conventional hatchery protocols or to replace naturally-reared Upper Willamette River Chinook salmon.

This project has two main objectives: 1) coordinate with RM&E principal investigators to provide wild fish surrogates for RM&E studies, and 2) conduct experimental research to determine factors contributing to the expression of diverse early life history phenotypes by Upper Willamette River salmonids. The results of experimental research completed under the second objective will provide necessary information to guide propagation procedures for producing wild fish surrogates that exhibit targeted phenotypes as determined under the first objective, thus optimizing performance of surrogate fish.

We have provided juvenile Chinook salmon as wild fish surrogates for RM&E researchers for juvenile fish passage studies in the North Santiam and McKenzie Rivers and are scheduled to provide wild fish surrogates over the next year for studies in the same rivers and Fall Creek. For rearing these surrogates, we received hatchery-origin juveniles from state fish hatcheries primarily as eyed-eggs, although brood year (BY) 2010 wild fish surrogates were received as fingerlings (Table 1). We have successfully delivered BY2010 juvenile Chinook salmon to researchers for spring release (2012) and BY2011 juveniles for fall release (2012) in reservoirs on the North Santiam and McKenzie Rivers (Table 2). All evidence suggested that these fish were smolting when delivered; therefore, their movement patterns should meet the expectations of the tagging studies. We will deliver BY2011 juveniles in spring 2013 and BY2012 juveniles for studies in fall 2013 and spring 2014 (see Table 2 for number and location of delivery).

We are currently evaluating the effects of temperature, rearing density, diet formulation, and substrate type on the development of juveniles by assessing growth patterns, body condition, morphology, proximate and fatty acid composition, and behavior. We are also assessing behavioral differences in spatial orientation such as surface versus bottom orientation and fish that choose to move downstream versus those that choose a "residency" lifestyle. Additionally, we are establishing measurable criteria for evaluating wild fish surrogates to determine how well they emulate phenotypes of naturally-reared Chinook salmon within the constraints provided by size and temporal requirements of RM&E studies.

Table 1.—Hatchery-origin juvenile Chinook salmon received for the wild fish surrogate project. Progeny from nine females from the pre-spawn mortality project were used for wild fish surrogates for the Middle Fork Willamette River. Otherwise, juveniles were provided by McKenzie and Marion Forks State Fish Hatcheries.

Brood year	Source	Developmental stage	Number
2010	North Santiam	Fingerling	
2011	North Santiam	Eyed egg	24,000
2012	North Santiam	Eyed egg	26,000
	McKenzie	Eyed egg	22,000
	Middle Fork	Adults	9 females

Table 2.—Hatchery-origin juvenile Chinook salmon that have been or will be delivered as wild fish surrogates for Willamette Valley Project RM&E studies (completed deliveries in italics). Wild fish surrogates were delivered to local state fish hatchery where RM&E researchers tag individuals prior to release.

Brood year	Location	Release	Tagging study	Number
2010	Detroit Reservoir	*Spring 2012*	JSATS	540
	Cougar Reservoir	*Spring 2012*	JSATS	540
2011	Detroit Reservoir	*Fall 2012*	JSATS	540
	Cougar Reservoir	*Fall 2012*	JSATS	540
	Cougar Reservoir	*Fall 2012*	Radio tag	1,700
	Detroit Reservoir	Spring 2013	JSATS	540
	Cougar Reservoir	Spring 2013	JSATS	540
2012	Detroit Reservoir	Fall 2013	JSATS	540
	Cougar Reservoir	Fall 2013	JSATS	540
	Cougar Reservoir	Fall 2013	Radio tag	1,700
	Fall Creek Reservoir	Fall 2013	Radio tag	1,100
	Detroit Reservoir	Spring 2014	JSATS	540
	Cougar Reservoir	Spring 2014	JSATS	540

PARASITIC COPEPOD INFESTATION ON SALMONID SPECIES REARING IN WILLAMETTE VALLEY RESERVOIRS

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High levels of parasitic copepod (*Salmincola califoriensis*) infestation on the gills of juvenile Chinook salmon have been observed by many researchers in WVP reservoirs. We quantified the frequency and intensity of infestation on all salmonids rearing above and within reservoirs from spring through winter, 2012. Preliminary results from this monitoring are reported here.

The frequency and intensity of gill infestation was significantly greater for reservoir-rearing juvenile Chinook salmon compared to stream-rearing juveniles above reservoirs. No copepods were observed during the summer on the gills of juvenile Chinook rearing above Lookout Point, Foster, and Cougar reservoirs whereas the proportion of reservoir-rearing Chinook with copepods present ranged between 17-49% during the same time period.

The frequency and intensity of infestation of copepods in Chinook gills increased with time spent in the reservoirs (Table 1). In the spring, infestation frequency on subyearlings was rare, occurring on 0-3% of the fish inspected, whereas by late fall gill copepods were observed on 86-100% of the subyearlings. The number of copepods attached to the gills of subyearlings ranged from 0-14 individuals. The highest level of copepods infestation was 23 individuals on the gills (and 11 attached to fins) on a 228 mm FL yearling in Cougar Reservoir.

Chinook appeared to be the most susceptible to infection. Kokanee appear to be least susceptible to infection and rainbow trout were intermediate (Table 1).

Table 1. Proportion of salmonids with presence of parasitic copepods on the gill by species and month in WVP reservoirs. Preliminary data.

Species (rear)	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				Cougar			
Chinook (W)	0.05	0.17	0.33	0.49	0.84	0.90	0.86
Rainbow	0.35						
Cutthroat	0.68						
				Detroit			
Chinook (W)				0.43	0.64	0.86	0.97
Chinook (H)			0.00	0.54	0.83	0.95	0.99
Rainbow			0.20	0.26	0.22	0.26	0.16
Rainbow (H)		0.76	0.33	0.45	0.29	0.44	n/a
Kokanee		0.00	0.00	0.02	0.00	0.00	0.01
				Lookout Point			
Chinook (W)		0.06	0.17	0.21	0.48	0.67	0.86
Chinook (H)		0.09	0.08	0.30	0.75	0.88	1.00
Rainbow		0.50	0.32				

REVIEW OF FISH RETURN DATA COLLECTED AT COUGAR FISH FACILTITY IN THE WILLAMETTE VALLEY, OREGON

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Biologist from the U.S. Army Corps of Engineers (USACE) operated two fish collection facilities in 2012 at Cougar and Fall Creek Dams. Cougar fish facility operated from March 13th-November 07th. A total of 522 chinook returned to Cougar (504 unmarked, 18 marked). In addition, we also collected 12 bull trout, 132 unmarked rainbow, and 65 unmarked cutthroat trout. We will present a summary of the data collected at the Cougar Fish Facility at 2012.

2012 HATCHERY RESEARCH MONITORING AND EVALUATION BY ODFW IN THE UPPER WILLAMETTE RIVER

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The ultimate goal of ODFW's Hatchery Research, Monitoring and Evaluation (HRME) program is to inform decisions on operation of the USACE Willamette Valley Hatchery Mitigation Program so that mitigation goals are met while minimizing negative impacts on naturally-produced, listed species and promoting their conservation and recovery.

Spawner surveys for Chinook salmon were conducted in the North and South Santiam rivers, McKenzie River, and Middle Fork Willamette River. Surveys were conducted below project dams for volitionally returning fish and above project dams for spawners trucked from hatcheries and other capture sites and "outplanted." We used the peak redd count expansion method to estimate spawner escapement whereby, (1) in each survey reach the largest redd count recorded over the course of the survey season was assumed to represent the total number of redds constructed, and (2) each redd represented 2.5 spawners . We used the cumulative redd counts collected during the 2008 through 2012 survey seasons to estimate average peak time of spawning in each subbasin below project dams. Carcasses were sampled during the survey season to obtain biometric data (fork length, spawning status, presence of fin clips, other marks and tags), and biological specimens (scales, DNA samples, otoliths). Essentially all hatchery-origin Chinook salmon receive an adipose fin clip and, as a secondary mark, a thermal otolith mark. Analysis of otoliths from unclipped fish allows verification that the fish were not unclipped hatchery fish. Importantly, otolith samples taken in 2012 have not yet been analyzed and we used data from 2011 to adjust estimates of natural- and hatchery-origin spawners. Video counts for all species were obtained at Bennett Dam on the North Santiam River and Leaburg Dam on the McKenzie River to estimate species and stock composition, run size, run timing, and proportion of hatchery origin spawners. Also, the timing of passage of unclipped Chinook salmon over Bennett and Leaburg dams was used to compare migration timing of run-of-river fish to migration timing of fish collected for Marion Forks and McKenzie hatcheries, respectively. Adult fish were sampled at hatcheries and traps to obtain data on origin, size, age structure, run timing and spawn timing as part of monitoring of broodstock collection and outplanting operations. Sampling of juvenile fish occurred at hatcheries and a trap at Willamette Falls (Oregon City, OR) to monitor fish performance both in-hatchery (survival, growth) and post-release (migratory performance).

Preliminary estimates of spawning activity (peak redd counts, escapement estimates, and redd densities), proportion of hatchery-origin spawners (pHOS) and prespawning mortality (PSM) rates are provided in Table 1. Estimates of pHOS exceed goals of 10% in every subbasin and tributary except in Fall Creek above Fall Creek Dam. Prespawning mortality rates were generally lower than in past years in all subbasins suggesting that environmental conditions in 2012 were relatively benign.

Counts of upstream migrants at Bennett and Leaburg dams are provided in Figure 1. The temporal distribution of upstream migrant unclipped Chinook salmon (assumed to be naturally-produced fish) was compared to the timing of adult fish collections for the corresponding hatcheries. Temporal distributions were similar except that in the McKenzie River late-returning hatchery fish were captured at the hatchery but did not appear in the Leaburg Dam counts (Figure 2, left panel). In the North Santiam late-returning naturally-produced fish were apparent but late-returning hatchery fish were not collected for brood (Figure 2, right panel). Comparison of spawn timing at the hatcheries to estimates of natural spawn timing indicate that peak spawn timing is similar in all cases but early and late spawning did not occur at the hatcheries (Figure 3).

Juvenile Chinook salmon of diverse sizes were released in the fall from the South Santiam, McKenzie and Dexter hatcheries (Figure 4, left panel) but, collectively, mostly larger fish migrated and were captured at Willamette Falls (Figure 4, right panel). Similar monitoring of spring-release Chinook salmon from all hatcheries is ongoing.

Table 1. Preliminary spawning and carcass survey results in 2012. Estimated naturally-produced and hatchery carcass counts and PHOS are derived from counts of clipped and unclipped carcasses adjusted using otolith results from 2011 (assumes similar proportions of unclipped hatchery fish in 2012).

Subasin, section	Peak Redd Count	Escapement Estimate (redds * 2.5)	Redd Density (redds/mi)	Unclipped Carcasses Sampled	Clipped Carcasses Sampled	Estimated Wild Carcasses	Estimated Hatchery Carcasses	pHOS	Spawned Females	Unspawned Females	PSM
North Santiam											
Bennett to Minto Dam	503	1258	21.4	99	281	94	287	75.3%	200	48	19%
Below Bennett Dam	9	23	4.5	8	35	8	35	81.4%	1	26	96%
Little North Santiam	45	113	4.8	24	3	22	4	15.4%	11	7	39%
Above Detroit	78	195	10.1	0	1	0	1	100.0%	1	0	0%
						124	**327**	**72.5%**			
South Santiam											
Lebanon to Foster Dam	443	1108	29.5	83	360	73	372	83.6%	247	90	27%
Below Lebanon Dam	0	0	0.0	0	10	10	10	50.0%	0	9	100%
Above Foster Dam	222	555	12.3	254	0	213	37	14.8%	100	17	15%
						296	**419**	**58.6%**			
McKenzie											
Above SF McK	183	458	4.0	92	2	87	7	7.4%	57	0	0%
Leaburg - S Fk Mck	184	460	10.2	43	12	41	14	25.5%	25	1	4%
Below Leaburg Dam	268	670	44.7	96	314	91	319	77.8%	210	75	26%
South Fork below Cougar Dam	67	168	15.6	14	4	12	6	33.3%	15	0	0%
South Fork above Cougar Dam	249	623	11.2	7	16	6	17	73.9%	19	0	0%
						237	**363**	**60.5%**			
Middle Fork Willamette											
Dexter–Jasper	76	190	8.4	11	44	8	47	85.5%	11	21	66%
NF Middle Fork above Lookout Point Dam	202	505	11.2	18	533	13	538	97.6%	216	68	24%
Fall Creek above Fall Cr. Dam	58	145	3.6	100	0	98	2	2.0%	39	6	13%
Little Fall Cr	31	78	6.1	4	26	3	27	90.0%	17	7	29%
Mid. Fk above Hills Creek Dam	656	1640	27.9	2	373	1	374	99.7%	209	22	10%
						123	**988**	**88.9%**			

Figure 1. Preliminary net upstream movement of fish at upper Bennett Dam, North Santiam River (right panel) and Leaburg Dam, McKenzie River (left panel).

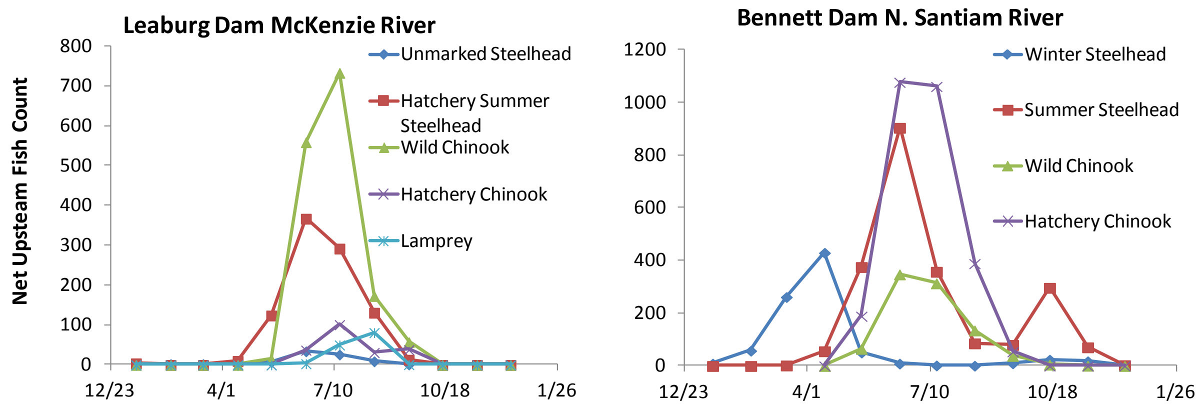


Figure 2. Comparison of run timing of unclipped Chinook salmon passing Leaburg (left panel) and Bennett (right panel) dams and collection timing for hatcheries.

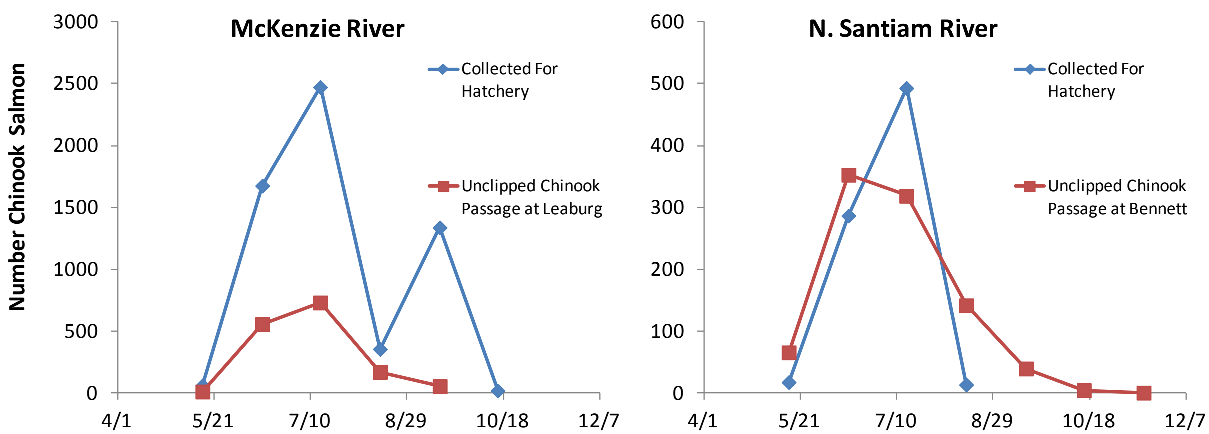


Figure 3. Cumulative redd counts (2008 - 2012: symbols), fitted curve (orange), estimated date of peak spawning activity (blue circles), and hatchery spawning (red).

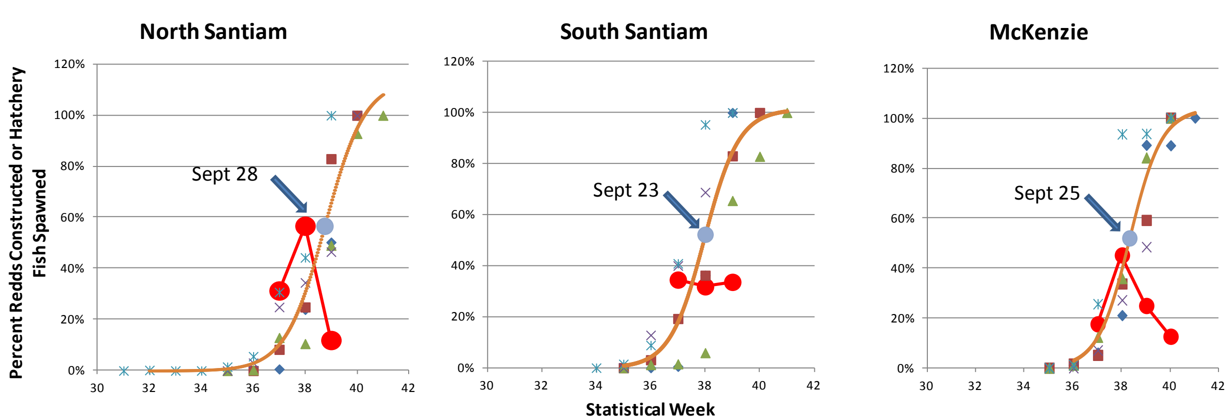
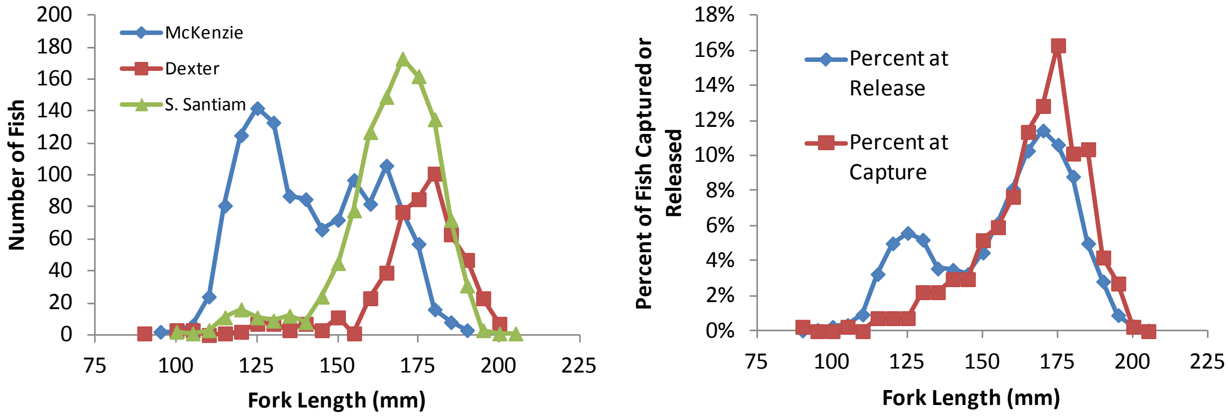


Figure 4. Typical size distributions of fall-release Chinook salmon from UWR hatcheries at release (left panel) and at capture at Willamette Falls (right panel) in 2012.



LIFETIME REPRODUCTIVE SUCCESS AND THE COHORT REPLACEMENT RATE FOR CHINOOK SALMON OUTPLANTED ABOVE COUGAR DAM, SOUTH FORK MCKENZIE RIVER

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Approximately 40 km of high quality spawning and rearing habitat was rendered inaccessible to spring Chinook salmon *Oncorhynchus tshawytscha* with the construction of Cougar Dam on the South Fork McKenzie River, Oregon. However, hatchery spring Chinook have been released above the dam since 1997, for the purposes of reintroduction and to provide a prey base for native bull trout *Salvelinus confluentus*. Completion of a fish trap-and-haul facility in 2010 now allows naturally produced spring Chinook to be collected at the base of the dam and released above the reservoir.

Using samples from all adult Chinook released above the dam since 2007, including unmarked Chinook that entered the trap-and-haul facility since completion, we have performed genetic pedigree analyses to evaluate total lifetime fitness of spring Chinook released above Cougar Dam. Total lifetime fitness is defined as the percentage of unmarked adult Chinook captured at the Cougar Dam trap facility that can be confidently assigned as progeny of spring Chinook salmon previously outplanted above Cougar Dam.

In 2012, the trap-and-haul facility caught 506 unmarked and 17 marked spring Chinook. Tissue samples and scales were collected from 499 fish for genetic pedigree and age assignments. In addition to the age-3 and age-4 unmarked adult Chinook sampled in 2010 and 2011, the collection of age-5 adults in 2012 potentially provided samples for all major age classes from the cohort produced by 2007 outplants. Of the 746 outplanted in 2007, 20% contributed to 2012 returning progeny. A larger proportion of fish that entered the Cougar Dam trap before July 30th assigned to progeny of previous outplants than after that date.

Our results suggested that total lifetime fitness had a positive relationship with number of mates and a negative relationship with outplant date. We found no relationship between total lifetime fitness and outplant location. Estimates for 2007 effective population size (Ne) for female spring Chinook ranged from 112 to146, with a cohort replacement rate of 0.38.

THE REPRODUCTIVE SUCCESS OF HATCHERY AND WILD SPRING CHINOOK RELEASED ABOVE COUGAR DAM, SOUTH FORK MCKENZIE RIVER, OREGON

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To mitigate for the negative effects of Willamette Project dams on native spring Chinook salmon *Oncorhynchus tshawytscha* and winter steelhead *O. mykiss* populations, hatcheries were established to offset lost natural production and associated harvest opportunities. In recent years, managers have passed spring Chinook salmon above these high-head dams in an effort to re-establish naturally spawning populations in their historic habitat. Adult Chinook outplanting has been implemented on the South Fork McKenzie River, where Cougar Dam impedes the upstream migration of adult salmon. When adult Chinook were passed above Cougar Dam, tissue samples, sex, outplant location, and outplant date were recorded.

Fin clips from young-of-the-year offspring produced by 2008, 2009, and 2010 adult outplants were sampled using a screw trap located at the head of Cougar Reservoir. All adults and about 2000 juveniles were genotyped each year using 11 highly polymorphic microsatellite loci. Using genetic pedigree, we estimated the reproductive success for each adult passed above Cougar Dam. This information was used to evaluate if outplanting date, location, sex, or year were significantly associated with differences in reproductive success. Three years of data suggest that sex and year significantly explained variation in reproductive success; however, outplant date and location did not. Our results suggest that the median reproductive success of males was between 0.63-0.88 times the median reproductive success observed for females ($p<0.001$), and that both 2009 ($p<0.0001$) and 2010 ($p<0.0001$) adults were less successful at reproducing compared to 2008 adults. In 2010 we had the opportunity to estimate reproductive success for both hatchery and wild salmon outplants and test for differences. Our results suggest that wild females were less successful at reproducing above Cougar Dam compared to hatchery females ($p = 0.05$). However, the median reproductive success for wild males was 1.04-6.40 times higher than hatchery males. Our results demonstrate the power of using genetic pedigree to study spring Chinook salmon outplanting strategies, as well as, differences in behavior between the sexes.

SPRING CHINOOK SALMON MOVEMENT AND DISTRIBUTION IN THE SOUTH FORK MCKENZIE RIVER ABOVE AND BELOW COUGAR DAM

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Similar to previous years, data collected from our screw trapping efforts in the South Fork McKenzie River upstream of Cougar Reservoir showed that a vast majority juvenile Chinook salmon (*Oncorhynchus tshawytscha*) enter Cougar Reservoir in the spring as fry, with an average size of 35 mm fork length (FL). We captured our first subyearling on March 5, 2012. The median migration date for subyearlings was May 16, 2012. Migration timing was very similar between South Fork McKenzie and the North Santiam Rivers. We captured 6,486 subyearling spring Chinook salmon and 8 yearlings throughout the 2012 trapping season. The estimated number of subyearlings that passed the trap in 2012 was 228,241 (95% CI ±34,715) compared to an estimate of 152,159 (95% CI ±26,665) in 2011.

Subyearlings transitioning from the river environment and entering Cougar Reservoir are generally associated with shallow, near-shore habitat. We assessed changes in subyearling Chinook salmon distribution along the shoreline of Cougar Reservoir by deploying floating box traps throughout the reservoir from April 10 – June 29. With each consecutive month, subyearlings dispersed further towards the dam along the shoreline, resulting in significantly different monthly distributions (KS test, $p \leq 0.001$) (Figure 1). In April, 73% of the subyearlings captured in our near-shore traps were in the upper third of the reservoir with only 2% in the lower third. By June, the proportion of subyearlings in the upper and lower third of the reservoir was 45% and 23%, respectively.

Beginning in June, subyearlings were also captured in our large Oneida traps set further offshore and tended to be larger than subyearlings caught in floating box traps. Median fork length of subyearlings collected in Oneida traps was 63 mm (range: 43-97 mm) compared to 47 mm (range: 33-70 mm) from floating box traps (Mann-Whitney Rank Sum Test; $p \leq 0.05$). The number of Oneida trap sets we were able to deploy in June was too limited to assess longitudinal distribution; however, our largest subyearling catches were in the middle and lower sections of the reservoir. This would suggest that subyearlings were distributed more evenly in June than was indicated by the catch of just smaller fish in floating box traps.

UPDATE FROM AN EVALUATION OF THE BEHAVIOR OF JUVENILE CHINOOK SALMON AT COUGAR RESERVOIR AND DAM: DATA FOR IMPLEMENTING A FISH PASSAGE SOLUTION

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A study of the movements and dam passage of hatchery and wild juvenile Chinook salmon (*Oncorhynchus tshawytscha*) at Cougar Reservoir and Dam was begun in 2011 to inform decisions about downstream passage alternatives. The study is ongoing and results presented will be based on data collected through December 23, 2012. Hatchery fish from the Wild Fish Surrogate project and wild fish captured within the reservoir were surgically implanted with acoustic transmitters and released from March-May (N = 468 hatchery fish only) and again from September-November (N = 449 hatchery, 65 wild). The transmitters were expected to function for about 90 days. Environmental conditions were similar to the normal operating procedures at the dam except for a controlled test of head differential inside and outside the temperature control tower (tower) in the spring (to see if a smaller differential and higher water velocities would entrain more fish), an altered operation of the regulating outlet (RO) and powerhouse in November, and a lower than normal pool elevation during December (as low as 1,500 ft compared to normal low of 1,532 ft). During the spring and summer the travel times from release near the head of the reservoir to the area within about 100 m of the tower was a median of 8.5 d, but ranged up to over two months. Fish made repeated directed (non-random) movements throughout the reservoir and rarely passed the dam. The proportion of fish arriving at the forebay hydrophones (reservoir passage efficiency, RPE) was 0.922 and the proportion of those fish that passed the dam (dam passage efficiency, DPE) was 0.111. Most of the dam passage occurred at night (78.7%). Fish that entered the tower rarely returned to the reservoir (2 of 37 fish detected there). The result of the head differential test (control $\leq$ 0.25 ft differential, treatment = 0.60-1.00 ft differential) was a doubling of the rate of tower entrance (hazard ratio = 2.007, P = 0.0805), but this was based on only 30 fish that entered the tower. During spring and summer the dam passage rate was primarily affected by diel period, with passage rates at night ranging from 3.1-4.9 times higher than those during the day, depending on the distance from the dam.

In the fall we collected data from hatchery and wild fish and passage proportions were greater than during the spring and summer. Travel times of hatchery fish from release to within about 100 m from the tower were a median of 3.7 d for hatchery fish and 11.7 d for wild fish. Conversely, the time from detection near the tower to dam passage was shorter for wild fish (median 5.8 d) than hatchery fish (median 39.8 d). The long times between arrival near the tower and dam passage are a result of the repeated non-random migrations of fish throughout the reservoir. The RPEs were 0.976 for hatchery fish and 0.708 for wild fish. The DPEs were 0.600 for hatchery fish and 0.674 for wild fish. As in the spring and summer, most fish in the fall passed the dam at night (94% for both hatchery and wild fish).

PASSAGE AND SURVIVAL PROBABILITIES OF JUVENILE CHINOOK SALMON AT COUGAR DAM AND DOWNSTREAM DURING FALL AND WINTER, 2012

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Dam passage and survival of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) at Cougar Dam was studied during November and December 2012. The goals were to estimate the effects of two novel operating conditions based on results of previous studies. In November an operation of regulating outlet (RO) use at night and powerhouse use during day (pool elevation 1,582-1,593 ft during fish releases) was used and in December the operation was continuous RO use with no powerhouse use (pool elevation of 1,504-1,511 ft during fish releases). Results were based two rearing two groups from the Wild Fish Surrogate project surgically implanted with radio transmitters released to enable use of the route-specific survival model to produce paired-release survival estimates. Fish were released about 0.8 km upstream from the dam, into the temperature control tower, and at a site 0.4 km downstream from the dam and detection sites were placed at several locations ranging from the dam forebay to a site near the confluence of the Santiam and Willamette rivers 218 km downstream. Transmitter life ranged from 45 d to over two months, so live transmitters may still be in the study area. As such, results are preliminary. Tagged fish ranged from 105-179 mm in length during the November study (N = 788) and from 112-180 mm during the December study (N = 713). Dam discharge during the release of fish averaged 1.6 KCFS during November and 1.8 KCFS during December. Median dam passage times of fish from the November and December studies from the release site 0.8 km upstream from the dam were 8.3 d and 0.8 d, respectively. Most fish released into the tower passed the dam within minutes. Most dam passage occurred at night (96% of fish released upstream in November, 95% of fish released upstream in December). Travel times from release to the end of the study area 218 km downstream ranged from 2 to 56 d and were slightly shorter for fish released in the tailrace (median = 2.4 d) than those released into the tower (median = 3.1 d). Passage and survival probabilities from the November study will be presented at the meeting.

REVIEW OF FISH RETURN DATA COLLECTED AT FALL CREEK FISH FACILTIY IN THE WILLAMETTE VALLEY, OREGON

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Biologist from the U.S. Army Corps of Engineers (USACE) operated two fish collection facilities in 2012 at Cougar and Fall Creek Dams. The Fall Creek Fish Facility operated from March 16th-November 30th. A total of 341 chinook (338 unmarked, 3 marked) returned to Fall Creek and we transported all of the unmarked fish upstream of the dam. A total of 2,258 large scale sucker returned to the fish facility we assume as a result of the full reservoir drawdown. We will present a summary of the data collected at the fish facility in 2012.

SPAWNING SUCCESS OF SPRING CHINOOK SALMON IN FALL CREEK AND THE NORTH FORK MIDDLE FORK WILLAMETTE RIVER, 2008-2012

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In recent years, high percentages (80-90%) of adult Chinook salmon transported above dams in some Willamette River tributaries have died prior to spawning. In 2012 we continued to survey the energetic status and prespawn survival rates of two populations of Willamette River spring Chinook salmon (Fall Creek and North Fork Middle Fork [NFMF]), monitored river environmental conditions, and investigated the relationships among prespawn mortality and a suite of potential causative factors. We also initiated a similar study on the South Fork Santiam River.

In 2012, a total of 118 Chinook salmon were sampled at Fall Creek. Fish were collected, assessed for energetic condition, PIT tagged and/or radio tagged, and then transported above the dam and allowed to spawn naturally. A total of 31 PIT- and radio-tagged salmon were recovered during spawning ground surveys on Fall Creek, a recapture rate of 26.3%. Prespawn mortality (PSM) rate was estimated to be 5.1% in the recovered tagged sample overall (20% for radio-tagged fish [1 of 5 females], 0% for PIT tagged fish [N=26]). Estimated PSM rate for untagged adults was slightly higher (16.7%, N = 30). Relatively cool water temperatures in 2012 were associated with lower PSM compared to previous warmer years. Water temperatures remained below 22°C (mean during study period was 14.8 °C) with peak temperatures occurring in mid-August, relatively late compared to previous study years.

Ten of the radio-tagged fish were released in Fall Creek reservoir to evaluate the potential of a reservoir release site to provide a summer hypolimnetic thermal refuge. Of the ten, 8 (80%) were recorded at the Fall Creek receiver site and two (20%) were recovered during upstream spawning ground surveys (both fish successfully spawned). A similar release of radio-tagged adults was conducted at Foster Reservoir to evaluate the hypolimnetic refuge concept and simultaneously evaluate whether reservoir releases could allow unclipped adults of unknown origin returning to Foster Dam to select among several potential natal spawning tributaries emptying into Foster Reservoir. Of the 33 radio-tagged adults released to the reservoir, 26 (79%) fish were last recorded in the South Santiam, 5 (15%) in the Middle Fork Santiam and 2 (6%) at Foster Dam. While it remains unknown if these adults homed to their natal tributaries, the results indicate low mortality was associated with reservoir release and that adults select multiple tributaries from within reservoirs.

One hundred fifty-four Chinook salmon collected at the Dexter trap were outplanted into the NFMF Willamette River in 2012. Overall, 28 (18.2%) of the PIT and radio-tagged fish were recovered during carcass surveys. PSM of immediate NFMF outplants was 9.2% for PIT- and radio-tagged fish. To assess the effects of holding fish on PSM an additional 96 Chinook salmon were sampled and held at Willamette Hatchery in Oakridge, Oregon. Seventy-five of these fish were then outplanted to the NFMF prior to spawning. Seventeen (22.7%) of the 75 fish were subsequently recovered on the spawning grounds. The PSM rate for the hatchery-held group was 10%. The low PSM rate observed in both groups was associated with cool river temperatures in 2012 (mean = 11.8 °C during the study period), a pattern also observed in other study years. These results, in combination with those from previous years suggest that holding fish prior to outplanting may reduce PSM in years with stressful in-stream conditions but may be of little benefit in relatively cool years such as 2011 and 2012.

We are currently conducting analyses across the four (2009-2012; NFMF) or five study years (2008-2012; Fall Creek) and will present preliminary results of these analyses. Overall, results of the project to date in combination with data from other sources suggest that: 1) there is an association between PSM rate and water temperature encountered during holding, 2) the specific causes of individual PSM events differ, and 3) and the primary mechanisms include interactions among fish condition, disease status, energetic status, and environment (e.g., temperature, collection and handling regime).

JUVENILE SPRING CHINOOK MIGRATION IN THE MIDDLE FORK WILLAMETTE RIVER AND USE OF LOOKOUT POINT RESERVOIR

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Timing and size of juvenile Chinook salmon entering Lookout Point Reservoir, their longitudinal distribution, dispersion into the reservoir, and vertical distribution near the forebay are critical information needed to aid the design of effective downstream passage options. We monitored juvenile spring Chinook salmon migration timing and size into Lookout Point Reservoir using a rotary screw trap located above the reservoir. We assessed longitudinal distribution of subyearling occupying nearshore habitat in the spring using floating box traps, and assessed seasonal changes in vertical distribution for juveniles near the dam forebay by suspending gill nets at specific depth intervals from 0 to 27.4 m (0-90 ft). Results from preliminary analysis are reported here.

A majority of juvenile Chinook migrated into Lookout Point Reservoir in the spring, with a median migration date of 13 April. This migration timing was later than subyearlings observed in the South Santiam, and earlier than subyearlings from the North Santiam and South Fork McKenzie rivers. From February through April most juveniles (99%) caught in our trap were subyearling fry (mean fork length = 36 mm; range 31 - 47 mm). Juveniles demonstrated a greater size range (mean = 48 mm FL; range 32 - 84 mm) in May and June, presumably because these subyearlings reared longer in the North Fork Middle Fork Willamette.

In addition to natural production, approximately 95,000 hatchery Chinook were released into the head of Lookout Point Reservoir in April and May. The 20 April release of unmarked hatchery fry confounded our analysis of dispersion of naturally-produced fry into the reservoir. Prior to the first hatchery release, natural subyearlings were dispersed further into Lookout Point Reservoir when compared to Cougar Reservoir for the same time of year (Figure 1). Prior to the hatchery release, 48% of the subyearlings were captured in the upper third of the reservoir with 14% in the lower third. This was significantly different than Cougar Reservoir where 63% of the subyearling catch occurred in the upper third of the reservoir and only 10% in the lower section (KS test, $p \leq 0.001$). The higher percentage of subyearlings observed in the lower section of Lookout Point is even more notable given that Lookout Point is over twice as long as Cougar Reservoir. The greater relative dispersion of fry into Lookout Point Reservoir is likely due in part to their earlier immigration into the reservoir, which is approximately a month earlier compared to Cougar Reservoir. Subyearlings were smaller in the upper section of Lookout Point Reservoir compared to the lower sections, similar to size distribution observed Cougar Reservoir.

Vertical distribution patterns in Lookout Point Reservoir were characterized by Chinook increasing in depth from August to September followed by a return to the surface by November and December, similar to the pattern observed in Detroit Reservoir. In July, approximately 65% of juvenile Chinook were caught in gill nets set below 9 m (30 ft), and this proportion increased to 88% by August. In September and October, Chinook were more evenly dispersed throughout all depth ranges, but in November and December the majority were captured in the upper 9 m (30 ft) of the water column.

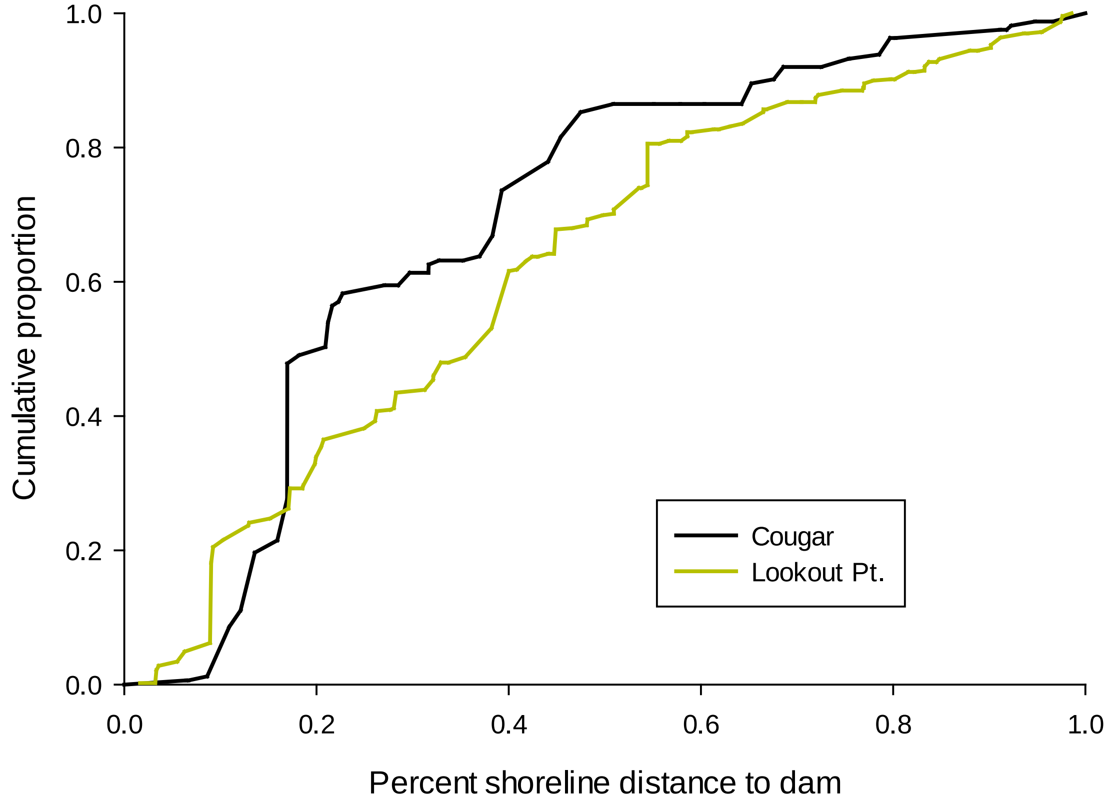

Figure 1. Cumulative proportions of subyearling catch prior to 20 April from nearshore floating box traps in Cougar and Lookout Point reservoirs in relation to percent of shoreline distance travelled from the head of the reservoir to the dam, 2012. The first hatchery release in Lookout Point Reservoir occurred on 20 April. Data are preliminary.

OUTMIGRATION OF HATCHERY SPRING CHINOOK SALMON RELEASED ABOVE AND BELOW DAMS IN THE MIDDLE FORK WILLAMETTE RIVER

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We released approximately 160,000 hatchery Chinook salmon *Oncorhynchus tshawytcha* >60 mm fork length tagged with passive integrated transponder (PIT) tags in 2011 and 2012 to estimate the effect that passage through Willamette Project dams and reservoirs has on outmigration success (relative survival to Willamette Falls), migration rate (km/d) and timing of juvenile spring Chinook salmon in the Middle Fork Willamette River. Fish were released into Hills Creek Reservoir, at the head of Lookout Point Reservoir (LOP), and below Dexter Dam. These releases were one task within a multi-year project that will also estimate juvenile-to-adult return rates for Chinook salmon using the PIT tags, coded-wire tags (CWT) and genetic markers.

Excluding the Hills Creek Reservoir group (no observations), the PIT tag interrogator in the Willamette Falls juvenile fish bypass detected 3.5% of the tagged fish through 31 October 2012. Substantially more fish were detected from the tailrace release group (n=3,243; 5.9%) than the LOP head of reservoir release group (n=721; 1.3%) and the proportions of fish detected were significantly different between groups (Z=40.892; P<0.001). Stated differently, fish released below the dams were detected at Willamette Falls 4.5 times more often than identical fish released above the dams, suggesting a much higher relative survival rate.

Migration rate was not significantly different between the 2011 paired release groups (P=0.166); however, in 2012 the tailrace release group migrated significantly faster (5.9 km/d) than the LOP head-of-reservoir group (4.7 km/d; P<0.001).

Some fish were recaptured and measured by other researchers, allowing us to estimate growth. Mean growth rates of LOP head-of-reservoir released fish were significantly higher (0.96 mm/d; n=319) than those released in Dexter tailrace (0.38 mm/d; n=92; P<0.001).

Incidental tag recoveries suggested a high level of predation, especially on the reservoir-released groups. In Hills Creek Reservoir, 85 PIT tags were recovered from the stomachs of crappie *Pomoxis* spp. caught by anglers; one large crappie contained 13 tags. Similarly, 42 crappie caught by anglers in LOP Reservoir contained 13 tags. ODFW reservoir researchers recovered 32 tags from the stomach contents of crappie, northern pikeminnow *Ptychocheilus oregonensis*, largemouth bass *Micropterus salmoides*, and walleye *Sander vitreus*. A single tag was detected in a cutthroat trout *O. clarkii* in the mainstem Willamette River. Finally, PIT tags from 11 fish presumably consumed by birds were recovered on East Sand Island in the lower Columbia River.

Our preliminary results demonstrate that Chinook salmon passing through the Lookout Point and Dexter projects grew faster but migrated slower and less successfully than those released below the projects. The markedly lower detection rate for reservoir-released fish is evidence for relatively low survival, most likely due to a combination of predation and passage mortality. The significance of higher growth in the reservoirs remains uncertain. We expect these data will be relevant to future evaluations of survivorship trade-offs between rapid-growth reservoir rearing and direct dam passage mortality. The apparently high levels of predation are a concern, but may have been influenced by artificially high prey density (i.e., releasing the tagged fish en masse). Additional releases are planned for 2013, and we expect to recover a small number of the CWT fish released in 2011 as age-3 adults.

PASSAGE BEHAVIOR AND SURVIVAL OF JUVENILE CHINOOK SALMON AT FALL CREEK DAM, 2012

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Since 2008, the Corps of Engineers has lowered Fall Creek Reservoir to 714 feet of elevation from the end of November until January, and in 2011 it was drawn down to streambed level (680 feet) for a period of 2 weeks. The complete drawdown resulted in an estimated 13,000 to 23,000 juvenile spring Chinook salmon (Oncorhynchus tshawytscha) passing the dam based on screw trap information. The objectives of this study were to collect information on behavior and passage survival relative to typical and alternative operations and determine if varying forebay elevations provide a benefit to migrating juvenile spring Chinook salmon.

We used 30 MHz radio telemetry monitoring systems to identify the magnitude and locations of mortality for juvenile Chinook salmon smolts between the upper end of Fall Creek Reservoir and the confluence of Fall Creek and the Middle Fork of the Willamette. We monitored the forebay entrance (approximately 2 km upstream of the dam), the forebay, the regulating outlet (RO), and the RO exit to evaluate juvenile Chinook salmon passage including diel behavior and movements into and within the forebay near the dam relative to typical and alternative operations (i.e. drawdown). Reservoir residence time, forebay residence time, dam passage efficiency, and estimates of reservoir, project, and dam survival for radio-tagged juvenile spring Chinook salmon passing through Fall Creek Reservoir and Dam will be reported.

Results from this study will directly contribute to examining key uncertainties and filling data gaps necessary for management actions, which will play a significant part in recovery of Willamette River spring Chinook salmon.

THE FALL CREEK DRAWDOWN: MONITORING RESULTS FROM YEAR TWO

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The U. S. Army Corps of Engineers (USACE) completed construction of Fall Creek Dam in the fall of 1965. Water impoundment began in January 1966, after the Oregon Game Commission chemically treated the reservoir area and tributaries to eradicate rough fish. Fall Creek Dam included upstream and downstream fish passage facilities. An evaluation of the fish passage facilities conducted by the Fish Commission of Oregon (1966-70) determined the emigrant passage facilities were ineffective, but noted large numbers of juvenile salmonids migrated from the reservoir using the regulating outlet gates (Smith and Korn 1970). From 1968-77 the reservoir elevation was lowered to streambed to facilitate fish passage and survival. This resulted in annual returns of spring chinook from 1,000 - 4,500 fish. Following the change to current operations annual returns ranged from 90-500 fish with an average of around 200. Changes in reservoir evacuation schedule beginning in 1977 are implicated with the smolt mortality and adult return problems observed at Fall Creek since 1980 (Downey 1992). Downey (1992) showed a 30% improvement in survival for juvenile outmigrants under low flow and low head conditions. In 2007, the USACE lowered Fall Creek Reservoir from elevation 728 ft. (minimum conservation pool) to elevation 714 to complete required maintenance on the intake structure. This operation was repeated in 2008-09. In 2010, the reservoir was lowered to 690 ft. to improve passage survival for outmigrating fish. In 2011-12, the USACE lowered Fall Creek Reservoir to elevation 680 ft. which resulted in a complete drawdown to streambed. This presentation summarizes preliminary data collected during the 2012 reservoir drawdown on fish passage timing, efficiency, survival, species composition, water quality, and the affect to downstream habitat.

MONITORING SEDIMENT LOADS AND WATER QUALITY DURING A SHORT-TERM DRAWDOWN OF FALL CREEK LAKE FOR DOWNSTREAM PASSAGE OF JUVENILE FISH, UPPER WILLAMETTE BASIN, OREGON

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In December 2012, the U.S. Army Corps of Engineers conducted an operational drawdown of Fall Creek Lake to allow for the downstream passage of Endangered Species Act-listed spring Chinook salmon in response to requirements in the 2008 Biological Opinion for continued operations of the Willamette Valley Project. For the drawdown, the lake elevation was lowered from the normal winter low-pool elevation of 728 feet to approximately 687 feet, allowing inflowing water to pass freely through the regulating outlet of the Fall Creek Dam for approximately 5 days. As one of a number of studies associated with this operational change, the U.S. Geological Survey monitored the sediment released and transported as a result of the drawdown. Continuous turbidity data and suspended-sediment samples were collected at the two inflows to Fall Creek Lake, Fall Creek below Fall Creek Dam, Little Fall Creek, and two sites on the Middle Fork Willamette River. Bedload samples were collected on Fall Creek approximately 0.75 miles downstream of the dam (USGS site 14151000, Fall Creek below Winberry Creek, near Fall Creek, OR) to measure the movement of material along the river bed during the drawdown. Continuous dissolved oxygen data also were collected at two sites to monitor the oxygen demand of the released sediment.

The initial release of sediment from the drawdown resulted in turbidity values that exceeded the maximum sensor range (3,000 Formazin Nephelometric Units [FNU], figure 1) at USGS site 14151000, and elevated turbidity values (maximum 513 FNU) at the site on the Middle Fork Willamette River at Jasper, OR (USGS site ID 14152000), approximately 10 miles downstream from the dam. Dissolved oxygen data were highly variable on Fall Creek and the Middle Fork Willamette at Jasper during the drawdown, likely due to sensor fouling from the large sediment release.

Regression models will be developed using in-stream turbidity, streamflow, and suspended- sediment concentration data to estimate sediment loads at each site and to calculate a sediment budget estimating the net sediment load released and transported from Fall Creek during the drawdown. Data generated from this project will allow the U.S. Army Corps of Engineers to determine if this annual operational modification is appropriate to provide downstream fish passage at Fall Creek Dam.

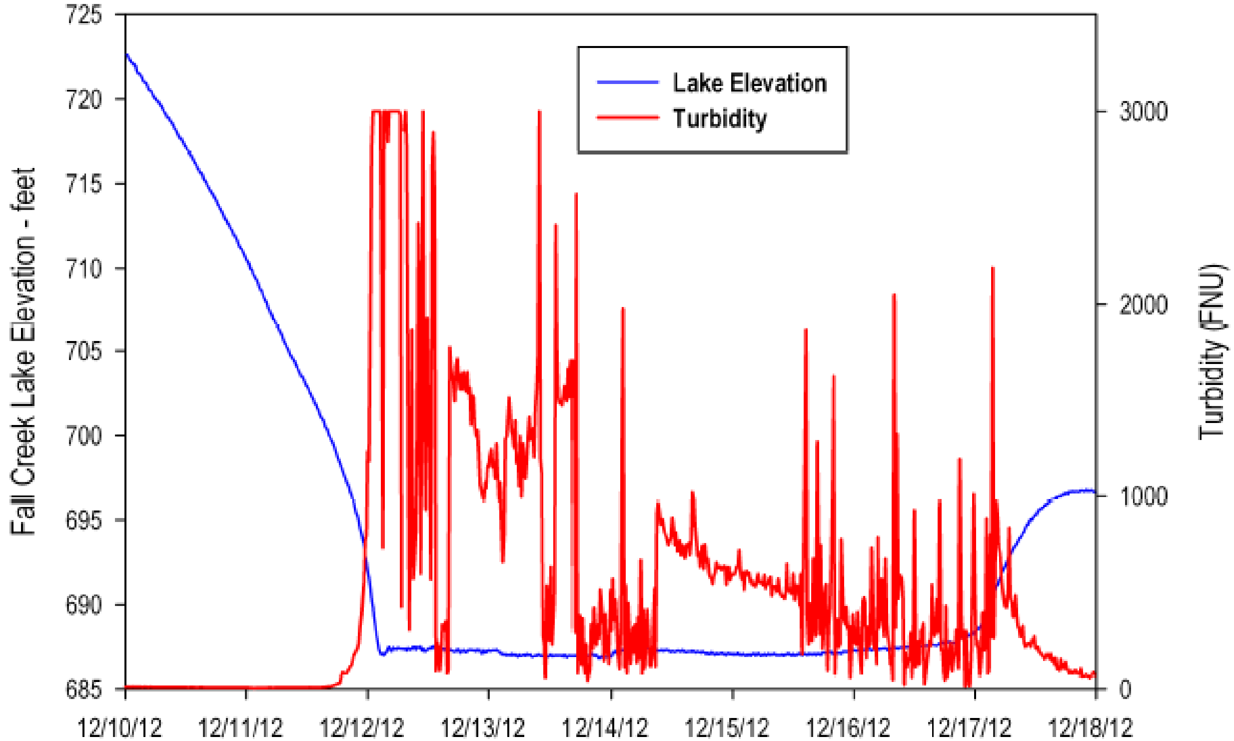

Figure 1: Continuous turbidity data from Fall Creek below Winberry Creek (USGS site 14151000), approximately 0.75 mile downstream of Fall Creek dam, during drawdown event. Data are provisional and subject to revision.

JUVENILE SPRING CHINOOK MIGRATION IN THE NORTH SANTIAM RIVER AND USE OF DETROIT RESERVOIR

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Information on juvenile Chinook salmon use of reservoirs, including entrance timing and distribution within the reservoir, are important in designing effective downstream passage options at Detroit Dam. We investigated juvenile Chinook salmon migration timing and size as they entered Detroit Reservoir, their vertical distribution near the dam forebay, and timing of dam passage. Migration timing information was collected with rotary screw traps located above and below the reservoir. We assessed seasonal changes in vertical distribution from summer through fall by suspending gill nets from the forebay log boom at specific depth intervals ranging from 0 to 27.4 m (0 - 90 ft). Preliminary results are reported here.

Limited numbers of adult Chinook outplanted above the reservoir in 2011 resulted in low subyearling catch at our trap above the reservoir in 2012 compared to previous years. However, subyearlings still comprised most the catch, with yearling smolts (2010 cohort) comprising only 7% of the total catch in the spring. Of the subyearlings captured, most (80%) migrated into Detroit Reservoir from April through June as fry, with a peak in mid-May. Mean fork length of subyearlings entering the reservoir in the spring was 35 mm (SE = 0.21) whereas yearlings entering the reservoir during the same period averaged 98 mm FL (SE = 6.1).

In addition to natural production, approximately 102,000 hatchery Chinook were released on 10 August, 2012 at the head of Detroit Reservoir (mean FL = 95 mm). We caught only one hatchery Chinook in gill nets near the forebay during three overnight sets from 14 - 16 August, at a distance approximately 13.5 km from the release site. As the hatchery Chinook dispersed, catch increased to 92 fish during four overnight sets from 21 - 24 August.

Vertical distribution patterns of Chinook were characterized by increasing depth from August to September followed by a return to the surface in November and December (Figure 1). Approximately 65% of juvenile Chinook caught in August were from nets set at 9 - 14 m (30-45 ft) depth. By September, the majority of Chinook were caught at depths between 14 - 18 m (45-60 ft). Chinook shifted back towards the surface beginning in October, and by December 71% were collected at depths between 0 - 4.6 m (0-15 ft).

Trapping below Detroit was disrupted from mid-January through mid-May, precluding us from collecting information on dam passage during this period. However, yearling Chinook were caught in early January and late May. No juvenile Chinook were collected from mid-June through late August. The first subyearling captured below the dam was in late August and we continued to catch subyearlings for the remainder of the year.

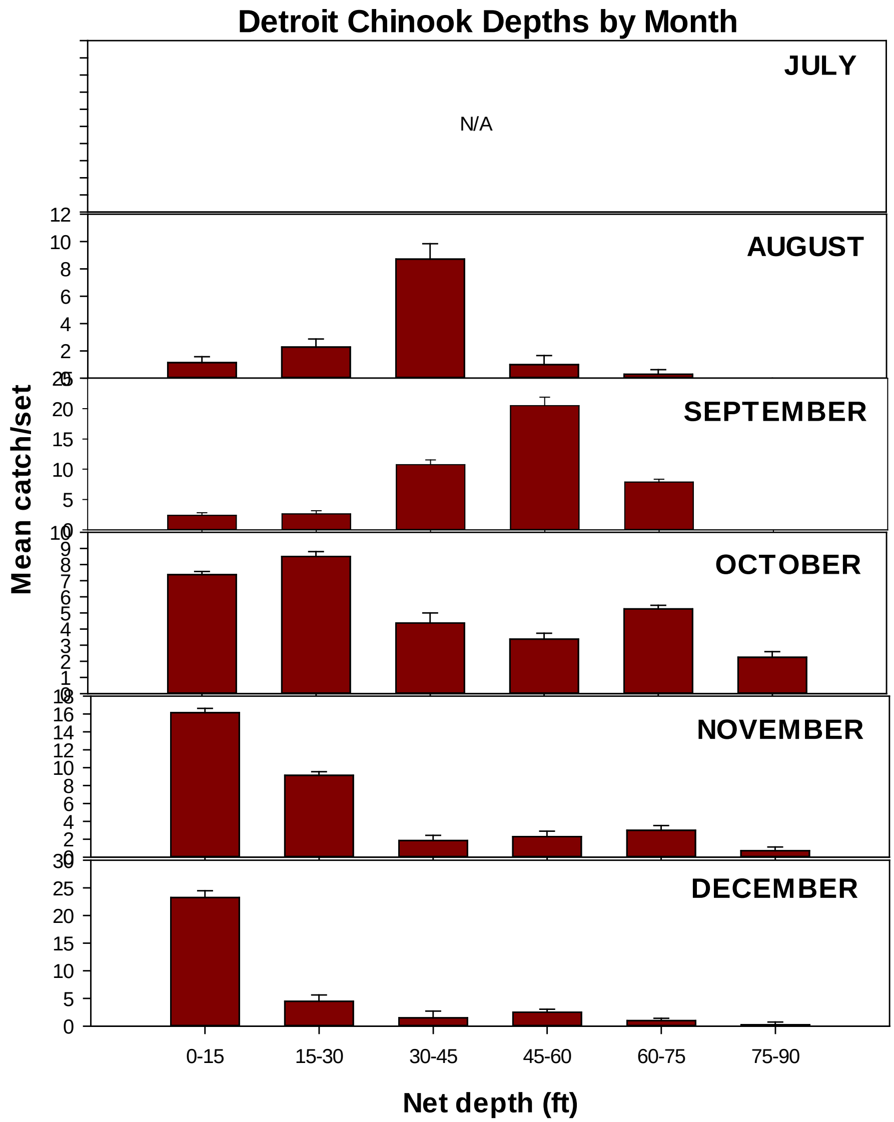

Figure 1. Mean catch per unit effort (CPUE) of juvenile Chinook in gillnets set a specific depth intervals near the Detroit forebay from July through December, 2012.

OUTMIGRATION OF HATCHERY SPRING CHINOOK SALMON RELEASED ABOVE AND BELOW DAMS IN THE NORTH SANTIAM RIVER

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We released two groups of approximately 12,500 hatchery Chinook salmon *Oncorhynchus tshawytcha* >85 mm fork length tagged with passive integrated transponders (PIT) above and below the Detroit and Big Cliff projects in August 2012 to estimate the effect that passage through Willamette Project dams and reservoirs has on outmigration success (relative survival to Willamette Falls), migration rate (km/d) and timing of juvenile spring Chinook salmon in the North Santiam River. These releases were one task within a multi-year project that will also estimate juvenile-to-adult return rates for Chinook salmon using the PIT tags and coded-wire tags.

Through 31 October 2012, the PIT tag interrogator in the Willamette Falls juvenile fish bypass detected 6.5% of the tagged fish. More fish were detected from the tailrace release group (n=889) than the head of reservoir release group (n=705) and the proportions of fish detected were significantly different (Z=4.717; P<0.001). The ratio of tailrace-released fish to those released above the dams was 1.3:1. The tailrace group migrated to Willamette Falls significantly faster (6.0 km/d) than the head of reservoir group (4.9 km/d; P<0.001).

Some fish were recaptured and measured by other researchers, allowing us to estimate growth. These fish had a median growth rate of 0.85 mm/d (n=70). No fish from the tailrace release group were recaptured during the reporting period, precluding a comparison between groups. No tags have yet been recovered through other sampling efforts.

Like our companion study in the Middle Fork Willamette River, preliminary results from this work indicate that juvenile hatchery Chinook salmon released above Detroit Reservoir grew rapidly, migrated more slowly, and were detected at a lower rate at Willamette Falls than identical fish released below the projects. However, the difference in detection rate (our measure of relative survival) of the two North Santiam River groups, while significantly different, was much less pronounced, suggesting better passage conditions and a lack of substantial in-reservoir losses (e.g., to predation). An important limitation to this study is that the tagged fish were released much later and at a larger size than naturally-produced fish that emigrate into Detroit Reservoir. Additional releases are planned for 2013 using smaller fish liberated earlier.

HYDROACOUSTIC EVALUATION OF JUVENILE SALMONID PASSAGE AT DETROIT DAM

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We performed an evaluation of juvenile salmonid passage and distribution at Detroit Dam (DET) on the North Santiam River in Oregon. The goal of the study was to provide fish passage and distribution data through all dam portals to support decision-making about long-term measures for enhancing downstream salmonid passage at DET and others dams in USACE's Willamette Valley Project. The fixed-location hydroacoustic technique was instituted to accomplish this study. The main findings from the hydroacoustic evaluation of juvenile salmonid passage and distribution at DET from February 2011 through February 2012 are as follows:

Comparison of Passage between Hydroacoustic and Screw Trap Datasets

- The hydroacoustic dataset included juvenile Chinook salmon, as well as kokanee (land-locked sockeye salmon), because both Chinook salmon and kokanee were captured in the ODFW tailrace screw trap when it was operated between April and December 2011.
- The comparison suggests a majority of fish represented in the hydroacoustic data may be kokanee during spring months and Chinook salmon in the summer, with similar proportions of Chinook salmon and kokanee during Oct. and Nov., and Chinook salmon as the majority of fish in Dec.

Turbine Passage

- An estimated 182,526 smolt-size fish (±4,660 fish) passed through the turbines between February 20, 2011 and February 12, 2012.
- Turbine passage rates for smolt-size fish (>~90 mm and <300 mm fork length) were highest during late fall, winter and early spring months (Figure 1). Passage was lowest during summer months.

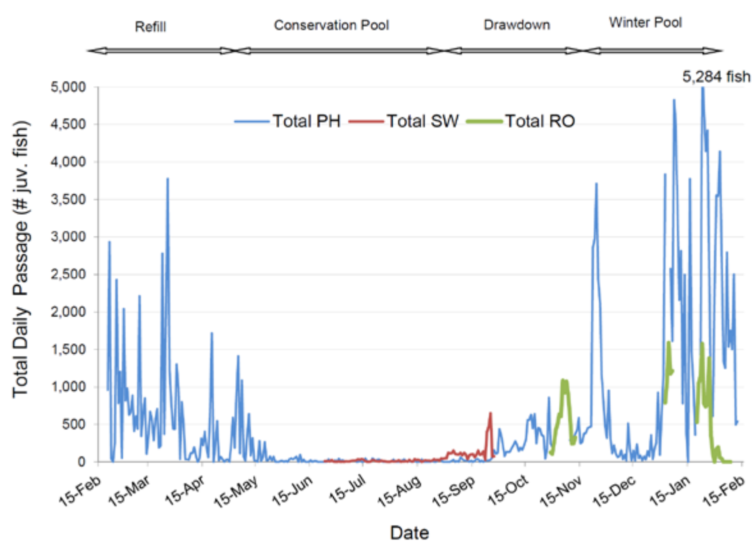

Figure 1. Estimated Total Daily Passage of Smolt-Size Fish at Turbines (PH), Spillway (SW), and Regulating Outlet (RO) – February 20, 2011 through February 12, 2012. Arrows at the top indicate four distinct pool elevation periods.

- Horizontal distribution for hours when both turbine units were operated simultaneously indicated Unit 2 passed almost twice as many fish as Unit 1.
- Diel distribution for turbine passage was fairly uniform, indicating fish were passing the turbines at all times of the day.

Spillway Passage

- A total of 5,083 smolt-size fish (± 312 fish, 95% CI) were estimated to have passed via the spillway when it was open between June 23 and September 27, 2011. From June 23 through September 22 when only Spill Bay 5 was open, we estimated 3,405 ± 188 (95% CI) fish passed via spill. Daily passage was low at the spillway during June through August, and increased in September (Figure 1).
- From September 23 through 27, the USACE conducted a "free flow" test by opening both Spill Bays 4 and 5. Forebay elevation started at approximately 470.5 m (~1,543 ft) on September 23 and ended at 469.7 m (1,541 ft) (crest elevation) on the morning of September 27. We estimated a total of 1,678 ± 248 (95% CI) smolt-size fish passed the two bays during this period. Daily spillway passage peaked on September 25 at 651 ± 157 (95% CI) fish.
- When the spillway (Bay 5) was operated simultaneously with the turbines (a total of 183 hours), spillway efficiency[1] was 0.72 and effectiveness[2] was 2.69. That is, when the spillway was open, 72% of the fish passing the dam used the spillway and 28% passed into the turbines.
- Horizontal distribution at the spillway for hours when Bays 4 and 5 were operated simultaneously indicated both bays passed similar numbers of fish.
- Diel distribution at the spillway (Spill Bay 5) shows a distinct peak in fish passage between mid-morning and mid-afternoon and low passage at night.

Regulating Outlet Passage

- We estimated that 23,339 smolt-size fish (± 572 fish, 95% CI) passed via the RO when it was open from October 29 through November 12, 2011, January 2 through 6, and January 20 through February 3, 2012. During the October–November period, RO passage peaked at 1,086 fish on November 5, with a second peak on November 7 (1,075 fish) (Figure 1). (The turbines were out of service November 1-8 and all water passed the dam through the RO during this period.)
- When the RO was operated simultaneously with the turbines (a total of 72 hours), RO efficiency was 0.33 and effectiveness was 0.89.
- Diel distribution for RO passage was variable, indicating fish were passing the RO all day.

Regression Modeling

- In multiple regression analyses, a relatively parsimonious model was selected that predicted the observed fish passage data well. The best model included forebay temperature at depth, forebay elevation, total discharge, hours of daylight, and the operation period.

Forebay Vertical Distribution

- The vertical distribution of smolt-size fish in the forebay near the face of the dam showed fish were generally distributed throughout the water column during all four operational periods. During the Refill and Conservation Pool periods, vertical distribution was bi-modal with surface-layer and

[1] Spillway efficiency is estimated as spillway passage divided by total project passage.
[2] Spillway effectiveness is estimated by the fish:flow ratio—proportion fish passage at a route (e.g., spillway) divided by proportion of water through that route out of the total project.

mid-water modes. Patterns for day and night distributions were variable. Fish were distributed above and below the thermocline when it was present (during Conservation Pool and Drawdown periods).

The spatially and temporally high-resolution data reported herein provided detailed estimates of vertical, horizontal, diel, daily, and seasonal passage and distributions and analyses of relationships between fish passage and environmental variables at DET from February 2011 through February 2012. This information is applicable to management decisions about the design and development of surface passage and collection devices to help restore Chinook salmon populations in the North Santiam River watershed above Detroit Dam and elsewhere in the Willamette Valley Project.

UPDATE FROM AN EVALUATION OF THE BEHAVIOR OF JUVENILE CHINOOK SALMON AND STEELHEAD AT DETROIT RESERVOIR AND DAM

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A study of the movements and dam passage of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) at Detroit Reservoir and Dam was begun in 2012 to inform decisions about downstream passage alternatives. The study is ongoing and results presented will be based on data collected through December 31, 2012. Hatchery fish from the Wild Fish Surrogate project were surgically implanted with acoustic transmitters and released from March-May (*N* = 468 juvenile Chinook salmon and *N* = 200 steelhead) and again from September-November (Chinook only, *N* = 514). The transmitters were expected to function for about 90 days. In the spring and summer juvenile steelhead took longer to travel from the release sites about 4 km upstream in the in the Breitenbush and Santiam rivers to the reservoir (median 41.2 d) than Chinook salmon (median 2.4 d). Once in the reservoir steelhead reached the log boom at the BRZ line faster than Chinook salmon (median 3.2 d versus 10.4 d) and the dam passage proportions of fish that reached the log boom (dam passage efficiency, DPE) were similar (0.794 steelhead, 0.774 Chinook). The DPE of Chinook salmon during the period in which spill was unregulated by tainter gates (like a spillway weir) was 0.617; this operation occurred prior to the arrival of the tagged steelhead. Dam passage percentages of steelhead were similar during the day and night, but more Chinook passed at night (67%) than during the day. Dam passage during spring was almost exclusively through the spillway and was positively related to spill volume. During the fall the travel times of Chinook salmon from release to the reservoir (median = 1.3 d) were generally similar to those in the spring. The median travel time from reservoir entry to the log boom was 8.6 d, which was several times longer than in the spring. In the fall most tagged fish passed via the turbines and regulating outlet (RO), because spill was rarely present. In the fall 5 tagged fish passed during spillway use (prior to 23 September; 2 via spill, and 3 via unassigned routes) and 77 passed when the pool elevation was lower than the spillway ogee (14.3% RO, 79.2% turbine, 6.5% unassigned). Dam passage in the fall was predominantly at night (80%). In the fall only 120 of the 514 fish were released before the spillway became unavailable due to the receding pool elevation. No tagged fish passed during the 2 d of spill unregulated by the tainter gates in the fall. Relatively few of the fish detected at the log boom in the fall passed the dam: the DPE was 0.209. The non–turbine passage proportion of the fish reaching the log boom (fish passage efficiency, or FPE) was 0.153, which due to the low number of fish passing the spillway, is essentially the RO passage proportion.

SPRING CHINOOK SALMON (ONCORHYNCHUS TSHAWYTSCHA) AND ONCORHYNCHUS MYKISS MOVEMENT IN THE SOUTH SANTIAM RIVER ABOVE AND BELOW FOSTER DAM

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Similar to previous years, data collected from our screw trapping efforts in 2012 upstream of Foster Reservoir showed that a vast majority juvenile Chinook salmon (*Oncorhynchus tshawytscha*) enter Foster Reservoir in the spring as fry, with an average size of 35 mm fork length (FL). We captured our first subyearling on January 6, 2012. The median migration date for subyearlings was March 7, and 97% of the subyearlings in the South Santiam River were collected prior to May 1, 2012. This was an earlier migration timing compared to other basins above WVP reservoirs. We captured 147 subyearling spring Chinook salmon and 1 yearling throughout the 2012 trapping season which was an increase from the 14 subyearlings and 1 yearling from the previous year.

In late June and early July we began catching subyearling *Oncorhynchus mykiss* in our screw trap upstream of Foster Reservoir. These subyearlings were presumably progeny from adult winter steelhead outplanted upstream of Foster Dam. We estimated the brood year (BY) for most of the fish using length frequency distributions. The peak of movement for subyearling *O. mykiss* (2012 BY) was in mid August. August *O. mykiss* catch accounted for 47% of our total 2012 BY catch for the year, and fish averaged 55 mm FL with a range of 29 – 77 mm. In 2012, we captured a total of 1,044 subyearling *O. mykiss* (2012 BY), 147 yearlings (2011 BY), and six larger fish that were not partitioned into a brood year category.

Below Foster Dam we operated a 2.4 m diameter screw trap just downstream of the turbine outflow. We captured hatchery and unmarked spring Chinook salmon, hatchery and unmarked *O. mykiss*, kokanee (*Oncorhynchus nerka*), cutthroat trout (*O. clarkii*), brown bullhead (*Ameiurus nebulosus*), yellow bullhead (*A. natalis*), crappie (*Pomoxis sp.*), yellow perch (*Perca flavescens*), smallmouth bass*(Micropterus dolomieu*), bluegill (*Lepomis macrochirus*), pumpkinseed (*L. gibbous*), northern pikeminnow (*Ptychocheilus oregonensis*), and largescale sucker (*Catostomus macrocheilus*). We captured 107 juvenile spring Chinook salmon between January 1 and April 24, 2012 ranging from 30 -77 mm FL, illustrating that spring Chinook salmon fry (< 50 mm FL) successfully pass through Foster Reservoir. Very few fish of any species were collected from May to September. The months with the highest abundance of fish captured below Foster Dam were November and December, including 72% of the overall *O.mykiss* catch for the year (74 unmarked, 2012 BY *O. mykiss*). This suggests that running the Foster fish weir from October through December may facilitate *O. mykiss* passage through Foster Reservoir.

CHARACTERIZATION OF FISH PASSAGE CONDITIONS THROUGH THE FISH WEIR AND TURBINE UNIT 1 AT FOSTER DAM

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and
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In May 2012, passage conditions at Foster Dam through a turbine and over the fish weir were evaluated using the HI-Z tag method (Normandeau and Associates) and Sensor Fish (Pacific Northwest National Laboratory) at two pool elevations – 616 ft MSL (low pool) and 634 ft MSL (high pool).

All treatment fish and Sensor Fish used in the study were released through the same fish release pipe systems. Two systems were used for the fish weir evaluation – a 4-in. pipe for juvenile fish releases and an 8-in. pipe for adult releases at each elevation. A 4-in. pipe system was used for the turbine releases. Four turbine operations through turbine Unit 1 were tested at the low pool elevation and three operations were tested at the high pool elevation. Maximum depth of the water passing over the weir was close to 2.5 ft and discharge ranged from 138-187 cfs. The water temperature during the study ranged from 7.0 to 9.0 °C.

HI-Z tagged treatment and control fish were equipped with a radio telemetry tag and HI-Z tags (balloon tags) that allow researchers to assess direct mortality and injury to turbine and/or spillway passed fish upon their recapture in the tailrace of the dam. Fish were assessed for condition at recapture, 1 and 48 h after release, and type and mechanism of injury were also determined. Injury and mortality rates were then calculated and compared to control fish rates. Sensor Fish are 24.5 mm by 90 mm cylindrical polycarbonate vessels containing angular rate-of-change sensors, accelerometers, and a pressure sensor. The onboard sensors give a detailed picture of passage conditions using pressure and acceleration magnitudes, recording passage travel conditions from release to the tailrace. Sensor Fish were tagged with radio and HI-Z tags. Following recovery, data were downloaded. Specific locations that contribute to injury and mortality and magnitudes of trauma-causing events within the passage route were identified. The estimated 48-hour survival for turbine passed juvenile steelhead (mean length 213 mm) at low pool (616 ft) ranged from 74.0% (6.0 MW) to 85.4% (7.0 MW) and for high pool ranged from 75.9% (6.5 MW) to 88.2% (5.0 MW). All control fish were recovered alive with tags intact. Malady-free (free of visible injuries, greater than 20 % scale loss, and loss of equilibrium) rates of turbine passed fish at low pool ranged from 71.5% (6.0 MW) to 81.9% (7.0 MW) and for high pool ranged from 73.9% (6.5 MW) to 80.7% (4.9/5.0 MW). The dominant injury type observed on turbine passed juvenile steelhead was severance or nearly severed (7.7 and 9.2%) for both test elevations.

The estimated 48-hour survival for juvenile steelhead (mean length 212 mm) passed over the fish weir at low pool was 99.5%; high pool survival was 94.4%. The malady-free estimates followed the same trend as survival and were 93.7 and 81.9% for low and high pool, respectively. The dominant injury observed on juvenile steelhead passing over the weir at low pool was gill and eye damage (3%) and for the high pool scrapes and bruises (14%). The estimated 48-hour survival for adult steelhead (mean length 708 mm) at low pool was 100%; estimate for high pool was 77.5%. The trend was the same for malady-free estimates at low and high pool with respective rates of 98.4 and 60.0%. The dominant injury observed for adult steelhead at low pool was bruises/scrapes (6%) and internal damage (24.5%) at the high pool. The standard errors (SE) of the juvenile survival and malady-free estimates ranged from 0.010 to 0.044. SE for adult fish were higher ranging from 0.00 to 0.101.

Sensor Fish experienced high damage/loss rates of over 22% during turbine passage. Evidence of grinding or squeezing was evident in several Sensor Fish units, assumed to be from being compressed between the turbine blade and wall. Sixty-two percent of the Sensor Fish experienced at least one significant event (an acceleration magnitude greater or equal to 95g) during turbine passage, as determined from acceleration magnitude data. For the low pool operations, events were most frequent at the wicket gates; for the high pool operations events were more prevalent during runner passage. Significant events having the greatest magnitudes were generally higher during the low pool than during high pool. The occurrence of more than one significant event during the passage of an individual Sensor Fish was more likely during high pool.

Significant event occurrences as experienced by the Sensor Fish were 2 to 3 times more frequent for Foster Dam Kaplan turbine passage than those observed during studies of Kaplan turbine passage at Columbia River Dams. A simulation model was used to estimate the possibility of fish being injured by a strike with the runner blade. The injury rates of balloon tagged fish corresponded well to injury probability model results. Lowest pressure nadirs observed during turbine passage were for the high head (high pool) operations. The observed nadir values for the Foster Dam turbine were similar in magnitude to those observed for Kaplan turbines installed in the mainstem Columbia and Snake river dams, ranging from approximately 14 to 21 psia. The ratio between the acclimation pressure and the lowest exposure pressure experienced during passage has been directly associated with mortal injury. Estimates of the probability of mortal injury due to barotrauma from passage through Foster turbines at the conditions tested would be approximately 10%.

Comparison of the Foster turbine passage survival/malady-free estimates of juvenile salmon with those obtained (HI-Z tagged) at other propeller/Kaplan turbines (130 tests at 18 projects) indicate that Foster survival and malady- free estimates are considerably lower than at most other projects. The number of blades (6), small size (100-in. diameter), and high rotation rate (257 rpm) contributed to inferior passage conditions at the Foster turbines.

All Sensor Fish passing over the weir experienced significant events. Shear events were observed during high pool, and all occurred at chute impact. All other significant events, for both low and high pool, were collisions due to shallow depth of flow and a poorly formed discharge jet. A total of 23% of the Sensor Fish passing over the weir at high pool were damaged following passage through the juvenile fish release pipe compared with 5% at the low pool. Impact forces from the fall to the concrete chute for both pool levels likely contributed to Sensor Fish damage and fish injury. The higher vertical drop (634 ft pool elevation) over the weir was particularly detrimental to the adult steelhead likely because of their heavier mass and the shallow depth (less than 1ft) of the weir discharge jet when it contacted the spillway chute. Although the weir shows potential as a safe route when deployed at an elevation 614 ft, further investigation is needed on its effectiveness of attracting fish away from the powerhouse at the different elevations. Possible changes to the weir design should also be investigated to improve the route's safety at both pool levels.

DATA COLLECTION FOR ASSESSING MERCURY LOADS INTO AND OUT OF COTTAGE GROVE LAKE, OREGON, 2011 AND 2012

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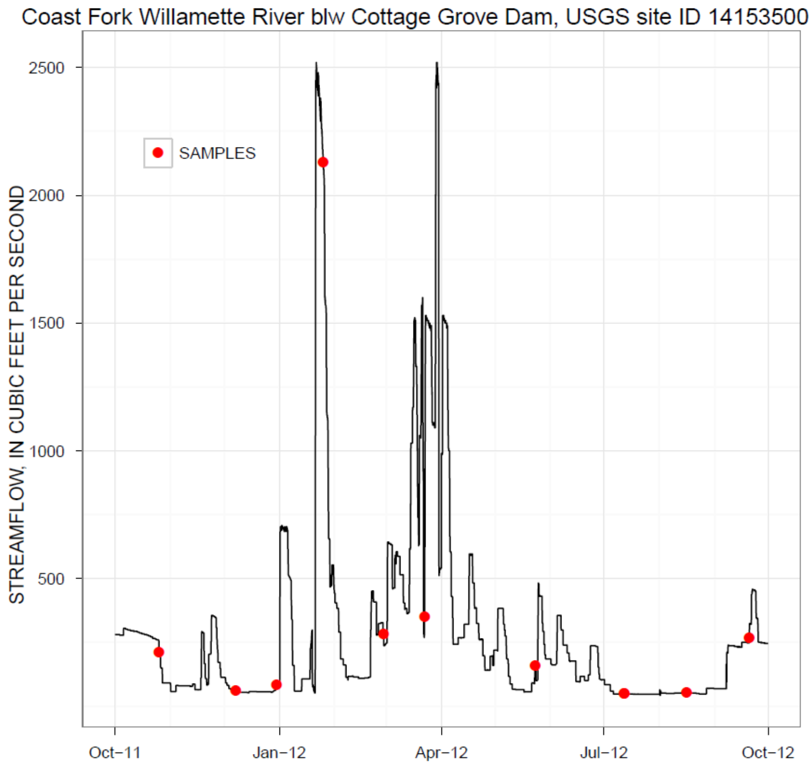
Cottage Grove Lake (CGL) is an impoundment of the Coast Fork of the Willamette River and is managed by the U.S. Army Corps of Engineers (USACE) as part of the Willamette Valley Flood Control Plan. The lake is currently under a fish consumption advisory because of elevated levels of mercury in fish tissue observed in an Oregon Department of Environmental Quality sampling survey in 2003. One probable source of mercury to the lake is mine tailings from the Black Butte mercury mine upstream of Cottage Grove Lake. The USACE provided funding to the U.S. Geological Survey (USGS) to collect mercury, dissolved-organic-carbon, and suspended-sediment samples at two sites (the inflow and outflow of CGL) from October 2011 to September 2012 to estimate a mercury budget for the Lake. An attempt was made to sample these sites over the range of the hydrograph during the project period (figure 1). Preliminary data show high concentrations of particulate total mercury and particulate methyl mercury (140 and 0.90 nanograms per liter, respectively) occurred in one sample at the inflow site during the first high flow event after the dry summer season ("first flush") on 12/30/2011, which also were associated with the highest concentrations of suspended sediment collected at that site (350 milligrams per liter). The highest concentration of particulate total mercury (15.0 nanograms per liter) on 3/22/2012 at the outflow site below Cottage Grove Dam, also was associated with the highest suspended-sediment concentration (51 milligrams per liter), but did not occur at a high streamflow relative to the hydrograph during the project period. Dissolved organic carbon concentrations were low at both sites, ranging from 1.1 to 2.4 milligrams per liter, except for a peak concentration of 6.6 milligrams per liter on 12/30/2011 at the inflow site. Continued collection of mercury, dissolved organic carbon, and suspended sediment data at these sites will give insight into the dominant source of mercury, the controls on mercury transport and bioavailability, and the relation of mercury concentrations to streamflow. These data will also support ongoing sampling efforts by the U.S. Environmental Protection Agency (USEPA) in Cottage Grove Lake, with the goal of assessing net methyl mercury production in the lake during different seasons and water-level changes. This collaborative effort between the USGS, USEPA, and the USACE will provide important information that can inform management decisions regarding lake operations.


Coast Fork Willamette River blw Cottage Grove Dam, USGS site ID 14153500
STREAMFLOW, IN CUBIC FEET PER SECOND
2500
2000
1500
1000
500
SAMPLES
Oct−11
Jan−12
Apr−12
Jul−12
Oct−12

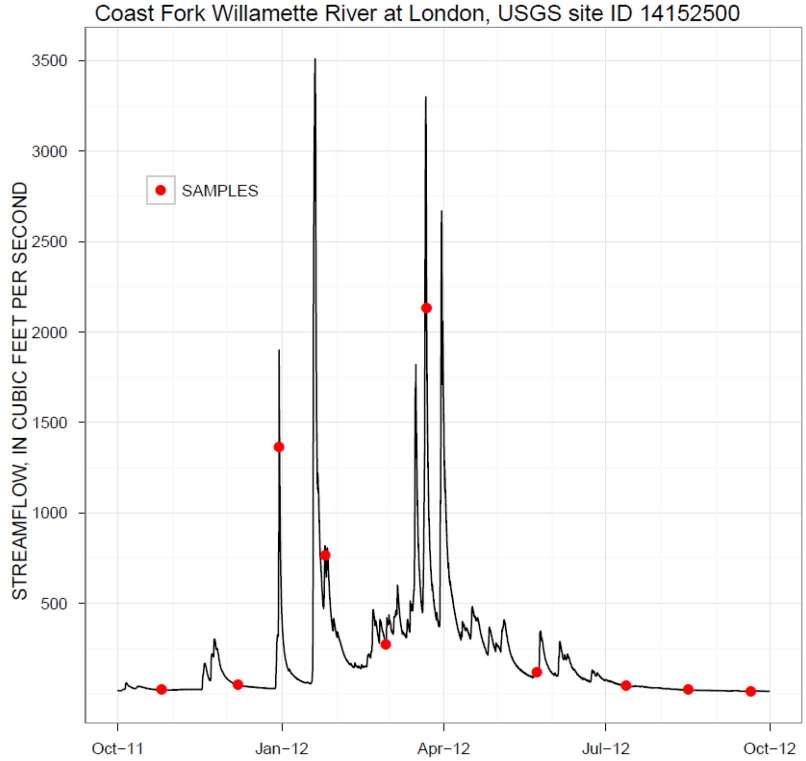


Figure 5: Locations on the hydrograph where samples were collected at the outflow (top) and inflow (bottom) of Cottage Grove Lake. Data are provisional and subject to revision.

MACROINVERTEBRATE DRIFT DENSITY AND COMPOSITION IN THE UPPER CALAPOOIA RIVER, OREGON DURING BASEFLOW CONDITIONS: IMPLICATIONS FOR RECOVERY OF ANADROMOUS SALMONIDS

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We examined macroinvertebrate drift density at baseflow along a 24 km reach of the Calapooia River (Oregon, USA). Flows steadily dropped during the experiment. At eight randomly selected locations 24 hr drift samples were collected on 8/5, 8/12, /8/19, and 8/26/2010. Samples were separated into twilight (3 hrs) and the rest of the day (21 hrs). Drift density ranged from 0.2-23 ind./m^3 and 0.022-1.365 mg/ m^3. Drift density abundance (p=0.32) and biomass (p=0.62) remained similar during the 22 day experiment. Within the 24 km reach drift density was usually higher upstream. Drift abundance and biomass was dominated by six taxa groups – Baetis tricaudatus, Calineuria californica, Hesperoperla pacifica, Simulium spp. and Chironomidae adults and larvae. These taxa comprised 65 and 75% of total abundance and biomass respectively. In individual models, B. tricaudatus (p<0.01), C. californica (p< 0.01), and H. pacifica (p<0.0001) had higher drift density biomass upstream. Biomass of Chironomidae (adults, p=0.11 and larvae, p=0.37) and Simulium spp. (p=0.07) were not different. During twilight, drift density biomass was higher for Chironomidae adults (p=0.013), Simulium spp. (p=0.04), H. pacifica (p < 0.0001), C. californica (p=0.01) as well as biomass overall (p=0.016). Stream temperature and drift information allowed estimation of energetic potential for Spring Chinook salmon and Winter Steelhead trout throughout the 24 km reach. The best energetic opportunities for growth of both species are in the upper half of the reach as down reach thermal conditions, even with high potential rations in some cases, limit potential. Like many watersheds managed for timber, the Calapooia River has poor instream habitat quality due to historical log transportation practices. Broad scale habitat reconstruction in the Calapooia and elsewhere that target areas with the best energetic potential should have a higher likelihood of success.

MONITORING THE RELATIVE ABUNDANCE AND DISTRIBUTION OF PACIFIC LAMPREY (ENTOSPHENUS TRIDENTATUS) IN THE WILLAMETTE RIVER BASIN

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With the rapid decline of Pacific lamprey (*Entosphenus tridentatus*) throughout its range, efforts have increased to fill critical knowledge gaps in its life history. The Willamette River appears to have one of the strongest remaining populations, and Willamette Falls is an important traditional harvest site to many Native Americans. The goal of our study is to provide information that will facilitate recovery and conservation efforts for Pacific lamprey in the Willamette Basin by completing two specific objectives: 1) monitor adult spawning activity by estimating redd density and distribution of spawning locations, and 2) identify rearing locations of larvae/ juveniles by estimating relative abundance and assessing associated stream habitats. During May – mid-June of 2012, we conducted spawning surveys for Pacific lamprey in Clear Creek, Thomas Creek, and the Marys River. We surveyed two segments in each stream multiple times by floating or walking. During each visit, we recorded numbers of live adults, carcasses, and redds, geo-referenced spawning locations, and measured associated habitat attributes. The number of redds km^{-1} varied among streams and between segments within a stream. A segment of Marys River had the lowest redd counts (17 km^{-1}), and a segment in Clear Creek had the highest counts (165 km^{-1}). Pool tail-outs had the highest percentage of redds in Clear and Thomas Creeks, but spawning locations classified as runs contained the majority of redds in the Marys River. Mean canopy cover of spawning locations for all stream segments was 34% (17 – 85%), and mean fish cover (e.g., boulders, logs) was 15% (5 – 40%). Dominant substrates at spawning locations consisted of coarse and fine gravels in Clear Creek and Marys River, whereas coarse gravel and cobble were dominant in Thomas Creek. During July – September, we conducted electrofishing surveys for larval lamprey at nine streams within major tributary sub-basins of the Willamette River, with each stream containing lower, middle, and upper reaches. Pacific lamprey was collected in 26 of 28 reaches, with varying CPUE across reaches. There was evidence of CPUE increasing longitudinally from upstream to downstream among the streams, suggesting that larvae were more abundant in lower reaches. Larval Pacific lamprey was positively associated with depositional areas containing deep, fine substrates, and particularly off-channel habitats (e.g., side channels, backwaters), where available. Pacific lamprey was also positively associated with brook lamprey (*Lampetra spp.*), indicating similar habitat use among lamprey species. Anthropogenic barriers appear to have limited the distribution of Pacific lamprey in some portions of the Willamette River basin. We hypothesize that the delivery and retention of fine sediment and gravels associated with multiple types of land-use practices are contributing to the decline of Pacific lamprey. Our distributional sampling and habitat assessments may be used to develop and refine a long-term monitoring program for Pacific lamprey, but further research of landscape-scale factors is needed to help inform recovery and conservation efforts for Pacific lamprey.

ASSESSMENT OF DISEASE OUTBREAK RISKS IN HATCHERIES IN THE WILLAMETTE RIVER SYSTEM

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Hatcheries are often perceived as a source of pathogen amplification, potentially increasing disease risk to wild populations; at the same time, wild fish may introduce pathogens into hatcheries through water sources. The goal of this project is to determine if pathogen transmission occurs between hatchery and wild fish. Data from the previous year indicated that pathogen transmission did not occur during baseline monitoring from hatchery fish to sentinel fish, but did occur during hatchery epizootic monitoring. In 2012, summer baseline monitoring was extended to see if pathogen events could be detected before outbreaks occurred at a hatchery, and hatcheries undergoing epizootics continued to be monitored.

To examine the potential for pathogen transmission, sentinel fish (juvenile rainbow trout and Chinook salmon) were exposed for 2 weeks at three Oregon hatcheries from August through the first week of October. Following the exposures, fish were returned to the Salmon Disease Lab and monitored for disease for 30 days. Sentinel fish were also exposed during *F. psychrophilum, F. columnare* (both at Dexter Ponds), and *A. salmonicida* (McKenzie Hatchery) outbreaks that occurred in September and October, respectively. Sentinel fish were also exposed among adult steelhead infected with Infectious Hematopoietic Necrosis Virus (IHNV, South Santiam Hatchery holding ponds). Water samples were collected at locations where sentinel fish were exposed during disease outbreaks. Samples collected during outbreaks of bacterial pathogens were vacuum-filtered, and individual aliquots were also inoculated onto bacterial media. To detect IHNV, 10 liter aliquots of water were filtered through tangential-flow filtration and inoculated onto cell culture. Low levels of nonpathogenic bacteria were detected in sentinels during baseline monitoring and during most epizootics. Minimal mortality occurred in all groups except fish held directly in the hatchery effluent during epizootics of *F. columnare* and *A. salmonicida*.

Additionally, we are surveying the prevalence of specific pathogens in wild or naturally-reared juvenile salmonid populations above and below hatcheries along the Willamette River Basin. Our survey targeted four hatcheries, and our sampling period was divided between two efforts at each site during the summer; followed by a sampling effort below a hatchery experiencing an outbreak of a bacterial pathogen in November. Juvenile fish were caught above and below four different hatcheries, euthanized, and analyzed for the presence of bacterial, viral, and parasitic pathogens. We observed low overall pathogen prevalence in fish above and below hatcheries; a few instances of *Renibacterium salmoninarum*, causative agent of Bacterial Kidney Disease, were detected at low-infection levels. Furthermore, we detailed the overall parasite load for each fish for comparison among and between sites. Although low pathogen levels suggest low impact, wild fish epizootics are ephemeral and difficult to document. In the future we plan to expand our survey to look at waterborne pathogen prevalence from congregations of spawning adult salmon through water sampling.

UPDATES ON OREGON CHUB RECOVERY AND RESEARCH, INCLUDING THE RESULTS OF MARKING AND MOVEMENT STUDIES.

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Oregon chub (*Oregonichthys crameri),* small minnows endemic to the Willamette Valley, were federally listed as endangered under the Endangered Species Act in 1993. In 2010, the species' status was upgraded to threatened, with the primary remaining threat being nonnative fishes, which are common in off-channel habitats preferred by Oregon chub. In 2009, we initiated a floodplain monitoring study to minimize impacts of incidental take of Oregon chub under the U. S. Army Corps of Engineers' Willamette Valley Biological Opinion (BiOp), with the objective of identifying those conditions (flow levels, temperature regimes, habitat characteristics) that may allow Oregon chub to co-exist with non-native fishes in connected habitats. In this multi-year study, we are assessing the impacts of altered flow and temperature regimes, floodplain restoration, and reconnection of off-channel habitats on habitat availability and fish assemblages downstream of Dexter Dam on the Middle Fork Willamette River. One element of this study is to determine the role of connectivity on movement patterns of Oregon chub. In 2011, we tested the effects of marking Oregon chub with PIT-tags (9 mm X 2.12 mm and 8.4 mm X 1.4 mm), visual implant elastomer (VIE) tags, and freeze brands on survival and the 150 d retention of these tags in the laboratory. We found low mortality and high retention rates with the smaller PIT tags, VIE tags, and freeze brands. In the summer of 2012, we assessed long term mark retention of VIE tags and freeze brands in the field at three vacant, hydrologically isolated ponds. In addition, we marked adult Oregon chub at two connected floodplain sites using a combination of VIE tags and freeze brands and documented movement out of one of these locations. We will discuss how results from these movement studies relate to species recovery, BiOp goals, and future research objectives.

BULL TROUT REINTRODUCTION EFFORTS IN THE UPPER WILLAMETTE BASIN – PAST, PRESENT, AND FUTURE

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Bull trout in the Willamette Basin experienced a substantial contraction in distribution over the past century. Populations were extirpated from the Clackamas, Santiam, and Middle Fork Willamette drainages by the 1990s and persisted only in the McKenzie River drainage. The interagency Upper Willamette Bull Trout Working Group has coordinated a comprehensive effort to recover bull trout in the upper Willamette River basin, and a primary component of this effort has been the reintroduction of bull trout to two streams in the upper McKenzie River basin where impassable culverts were renovated and to the upper Middle Fork Willamette River drainage.

We collected and directly transferred annual totals of 142–3,386 fry from Anderson Creek to recipient streams during February–May of 1993–2005. Fry were transferred to Sweetwater Creek from 1993–1999 (N = 6,377), to Olallie Creek in 1994–1997 (N = 670), and to the Middle Fork Willamette River drainage from 1997–2005 (N = 10,408). We detected spawning by adult bull trout in Sweetwater Creek in 2000, seven years after the first transfers of fry. Annual totals increased to 9 redds by 2005, then 20 to 22 redds in 2006–2009. In Olallie Creek, any effect of augmentation was unclear because bull trout spawned in the upstream reach in 1995, which was the first year access was restored and only one year after the initial transfer of fry. We first detected mature bull trout in the Middle Fork Willamette River drainage in 2005, eight years after initial transfers. However, total annual redd counts have remained low (up to 15 redds), and spawning has not been detected in Swift Creek where the majority of potential tributary spawning and rearing habitat exists. Low survival of fry released into Swift Creek inspired the Working Group to initiate a captive-rearing program in 2007 to evaluate survival of larger juveniles, and better survival among larger captively reared juveniles may lead to increased returns of spawning adults in coming years. Evaluation of this program and potential limiting factors has become a primary focus.

Recent reintroduction feasibility assessments have centered on the North Fork Middle Fork, Salmon Creek, and Salt Creek drainages. We have identified potentially suitable habitat in the upper Salmon Creek and Salt Creek watersheds, but both locations may also hold obstacles to successful reintroduction. Feasibility assessments for reintroductions in the Santiam Basin are in preliminary stages.