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JUVENILE SALMONID OUTMIGRATION MONITORING AT WILLAMETTE VALLEY PROJECT RESERVOIRS

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Executive Summary

To aid in the development of downstream passage options for juvenile salmonids at Upper Willamette reservoirs, we present in this report results from our screw trapping operations upstream and downstream of USACE project dams from the 2011 field season. Traps upstream of dams were located on the Breitenbush and North Santiam rivers upstream of Detroit Reservoir, the South Santiam River upstream of Foster Reservoir, the South Fork McKenzie River upstream of Cougar Reservoir, and the Middle Fork Willamette River upstream of Lookout Point Reservoir. +Traps were also located below Detroit Dam, Foster Dam, Cougar Dam, and Lookout Point Dam (Figure 1).

The objectives of this project were 1) to provide information on migration timing of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) into Willamette Project reservoirs, 2) to provide information on emigration timing of juveniles out of the reservoirs, 3) determine size at which juveniles enter and exit the reservoirs, 4) and estimate abundance of juvenile Chinook salmon entering reservoirs. This information will be used to inform management decisions regarding fish passage alternatives and to help gauge the success of the current adult outplanting program.

In 2011, all upstream traps were deployed during the first week of January and remained fishing throughout the calendar year. The majority of juvenile spring Chinook salmon entered Willamette Valley Project (WVP) reservoirs as fry (< 50 mm fork length) in the early spring, soon after emergence. We observed early fry migration in each of the sub-basins, indicating that fry outmigration appears to be a strong life-history characteristic for the Upper Willamette population of spring Chinook salmon. Yearlings entering reservoirs were rare and generally collected in late winter early and spring.

Fry typically entered reservoirs from February through June. River discharge, incubation temperatures, distance from spawning areas to reservoir entry, and quality of upstream rearing habitat can each affect reservoir entry timing and size of juvenile Chinook salmon. The peak of reservoir entry for subyearlings outmigrating from the North Santiam River was April-June with a median migration date of May 6. Peak migration in the Breitenbush River was February-March with a median date of March 8. Differences in migration timing between these two sub-basin was likely the result of different stream temperature profiles resulting in earlier development and emergence in the Breitenbush River. In the South Santiam above Foster Reservoir, only 14 subyearlings were collected, all in January. We suspect a high flow event and scouring in mid-January caused a near complete recruitment failure of Chinook salmon in the South Santiam River, and likely decreased recruitment in other sub-basins. Similar to the North Santiam population, the peak immigration of subyearlings in the South Fork McKenzie River was April-June with a median migration date of May 16. Based on catch in our Middle Fork Willamette trap, peak reservoir entry into Lookout Point Reservoir was January-June with a median date of March 28. At this trap, we had a spike in fry catch in January that we suspect was associated with a high flow event.

The average fork length (FL) of fry entering most WVP reservoirs in the spring was 35 mm. Subyearlings did not show growth until June. The exception to this were migrants collected at the Middle Fork Willamette trap which exhibited the largest variation in size at the time of reservoir entry for any of the rivers sampled. We suspect this is partly due to the greater extent of rearing habitat between spawning areas and our trap in this sub-basin, allowing some juveniles to rear prior to capture in our trap.

Data collected from our trapping efforts below dams indicated that very few fry continue migration through the reservoirs in the spring. We captured few fry in traps below Cougar and Lookout Point dams in 2011. The Foster Dam trap was not operated until late summer after the majority of fry migration had taken place in other sub-basins. Most juvenile spring Chinook salmon exit WVP reservoirs as subyearlings in late fall/winter (Oct-Feb), in conjunction with reservoir drawdown and lowered pool elevation. The exception to this was Lookout Point Reservoir, where the greatest juvenile Chinook salmon catch was between May and July during spill operations.

Based on downstream tag detections for juvenile Chinook salmon captured, tagged and released below Cougar Dam, there appeared to be greater delayed mortality associated with fish that exited through the regulating outlet compared to the turbines under certain operating conditions. Catch rates of traps located below Cougar Dam indicated that majority of juvenile Chinook salmon (91%) selected the regulating outlet when flows through the two routes were split approximately equally. When flows were redirected so approximately 67% of the flow passed through the turbines, only 44% of the fish exited via the regulating outlet. A 17% increase in flow toward the tailrace resulted in a 47% increase in the percentage of fish directed toward the turbines.

Subyearlings leaving WVP project reservoirs in November varied greatly in size. Lookout Point Reservoir juveniles were the largest on average (212 mm FL), followed by those leaving Detroit (172 mm), and Cougar Reservoir had the smallest outmigrants (132 mm). There were not enough juveniles captured below Foster Dam trap to compare to the other reservoirs.

Juvenile winter steelhead (*O. mykiss)* were captured in the South Santiam screw trap throughout the sampling season with the greatest catch occurring from August through December. Two year classes of *O. mykiss* were again evident through most of the trapping season based on fish length; we also captured a few resident adult rainbow trout >200 mm FL.

Population estimates were calculated for the North Santiam River upstream of Detroit Reservoir, and the South Fork McKenzie River upstream of Cougar Reservoir. Migrant estimates were based on screw trap recapture information. In the North Santiam we captured 4,255 Chinook salmon subyearlings, and estimated 587,960 (95% CI ± 193,708) subyearling migrants entering Detroit Reservoir. The vast majority of subyearlings in 2011 moved into Detroit Reservoir as fry from April through June (88%), which comprised the peak months of migration. Trap efficiency (TE) ranged from 0.8 to 1.9% with a weighted yearly TE of 1.4%. The large variance surrounding the estimated number of migrants is the result of the low trap efficiency associated with this site.

In the South Fork McKenzie we captured 4,348 Chinook salmon subyearlings, and estimated a total of 152,159 (95% CI ± 26,665) subyearlings that migrated into Cougar Reservoir. This estimate for Cougar Reservoir was much lower than the 2010 estimate of 685,723 (95% CI ± 72,519). Variables contributing to the lower number of migrating subyearlings in 2011 (2010 brood year) include the reduced number of females outplanted upstream of the reservoir in 2010, the corresponding number of redds that would produce the 2011 cohort of subyearling migrants, and the high flows that were present in mid-January. The vast majority of subyearlings in 2011 moved into Cougar Reservoir as fry from April through June (90%), which comprised the peak months of migration. Trap efficiency ranged from 1.5 to 23.5% with a yearly weighted TE of 2.9 %.

Introduction

Spring Chinook salmon *Oncorhynchus tshawytscha* and winter steelhead *O. mykiss* in their respective upper Willamette River Evolutionarily Significant Units (ESU) are listed as threatened under the Endangered Species Act (NMFS 1999a; NMFS 1999b). As a result, the National Marine Fisheries Service (NMFS) must evaluate any action taken or funded by a federal agency to assess whether the actions are likely to jeopardize threatened and endangered species, or result in the destruction or impairment of critical habitat. The 2008 Willamette Project Biological Opinion (BiOp; NMFS 2008) outlined the impacts of the Willamette Valley Project (WVP) on Upper Willamette River (UWR) Chinook salmon and winter steelhead. The WVP consists of 13 dams and associated reservoirs managed jointly by the U.S. Army Corps of Engineers (USACE), Bonneville Power Administration (BPA), and Bureau of Reclamation, collectively known as the Action Agencies. The Biological Opinion detailed specific actions, termed Reasonable and Prudent Alternative (RPA) measures that would "…allow for survival of the species with an adequate potential for recovery, and avoid destruction or modification of critical habitat".

A number of RPA measures in the Willamette Project BiOp are associated with downstream fish passage through project reservoirs and dams. These include RPA measures 4.2 (winter steelhead passage), 4.7 (adult fish release sites above dams), 4.8 (interim downstream fish passage through reservoirs and dams), 4.9 (head-of-reservoir juvenile collection prototype), 4.10 (downstream juvenile fish passage through reservoirs), 4.12 (long-term fish passage solutions). Currently, numerous passage designs and operational flow modifications are under consideration to improve downstream passage and survival of juvenile migrants. Improving passage requires a basic understanding of the size, timing, and abundance of juvenile salmonids that enter and exit the reservoirs.

To aid in the development of downstream passage options, we present results from our operation of rotary screw traps in rivers upstream of Detroit, Foster, Cougar and Lookout Point reservoirs, and at the tailrace of Detroit, Foster, and Cougar dams. We also summarize data collected from traps located below Lookout Point Dam that were operated by USACE personnel. The objectives of this study were to provide information on the migration timing and size of naturally produced juveniles entering and exiting reservoirs. We also provide information on abundance of migrants at traps where estimates were possible. All juvenile Chinook collected upstream of the reservoirs are progeny from adults that were trapped and hauled upstream of WVP dams. Juveniles collected in the Middle Fork Willamette trap also included hatchery fish released in Hill Creek Reservoir. Juveniles collected below dams include natural-produced progeny as well as hatchery fish released into some reservoirs (Detroit and Lookout Point reservoirs).

This report fulfills a requirement under Cooperative Agreement Number W9127N-10-2-0008, covering activities of April 2011–March 2012. Activities were implemented by ODFW on behalf of the USACE to assist with meeting the requirements of the RPA measures prescribed in the Willamette Project BiOp of July 2008 (NMFS 2008). The USACE provided funding for monitoring activities. Primary tasks included: 1) continue to further develop and maintain current monitoring infrastructure (easements and permits) 2) monitor juvenile salmonid outmigration to provide information on migration timing and size; and 3) estimate abundance of outmigrating UWR Chinook salmon. The data reported here covers field activities up to December 31, 2011.

Methods

Monitoring Infrastructure

Traps upstream of dams in 2011 were located on the Breitenbush and North Santiam rivers upstream of Detroit Reservoir, the South Santiam River upstream of Foster Reservoir, the South Fork McKenzie River upstream of Cougar Reservoir, and the Middle Fork Willamette River upstream of Lookout Point Reservoir (Figure 1). All rotary screw traps above project reservoirs were 1.5 m in diameter. We also operated, and added trapping sites below USACE project dams in 2011. We installed 2.4-m diameter rotary screw traps below Detroit and Foster Dams, continued operation of the four screw traps below Cougar Dam (two 2.4-m traps in the turbine tailrace, two 1.5-m traps in the regulating outlet) and received and summarized migrant data for two 2.4-m traps operated by the USACE below Lookout Point Dam (Figure 1).

Juvenile Salmonid Outmigration Timing and Size

We used 1.5-m rotary screw traps to capture juvenile spring Chinook salmon migrating downstream between spawning grounds and WVP reservoirs. The South Santiam trap was located downstream of adult winter steelhead outplanting locations which facilitated data collection for juvenile steelhead migration in addition to spring Chinook salmon. Traps were operated continuously throughout the year unless flows (high or low) were prohibitive (Figure 2). Traps were checked and cleared of fish and debris once per day when weather conditions permitted, with more frequent visits during storm events or periods of high debris transport. Fish abundance numbers reported for trapping efforts reflect actual trap catch and were not adjusted for trap efficiency or days when the trap was not operated unless otherwise stated.

Fish captured and removed from traps were anesthetized with MS-222 and enumerated by species and age class (subyearling, yearling). We measured fork length (FL) to the nearest mm from a subsample of fish collected (~100/wk) and released all fish approximately 100 m downstream of the trapping site upon full recovery from anesthesia, unless retained for trap capture efficiency tests. Chinook salmon juveniles >65 mm FL captured in screw traps were PIT tagged (Appendix A; Table A1) to collect recapture and detection information regarding growth and migration behavior (Appendix A; Table A2).

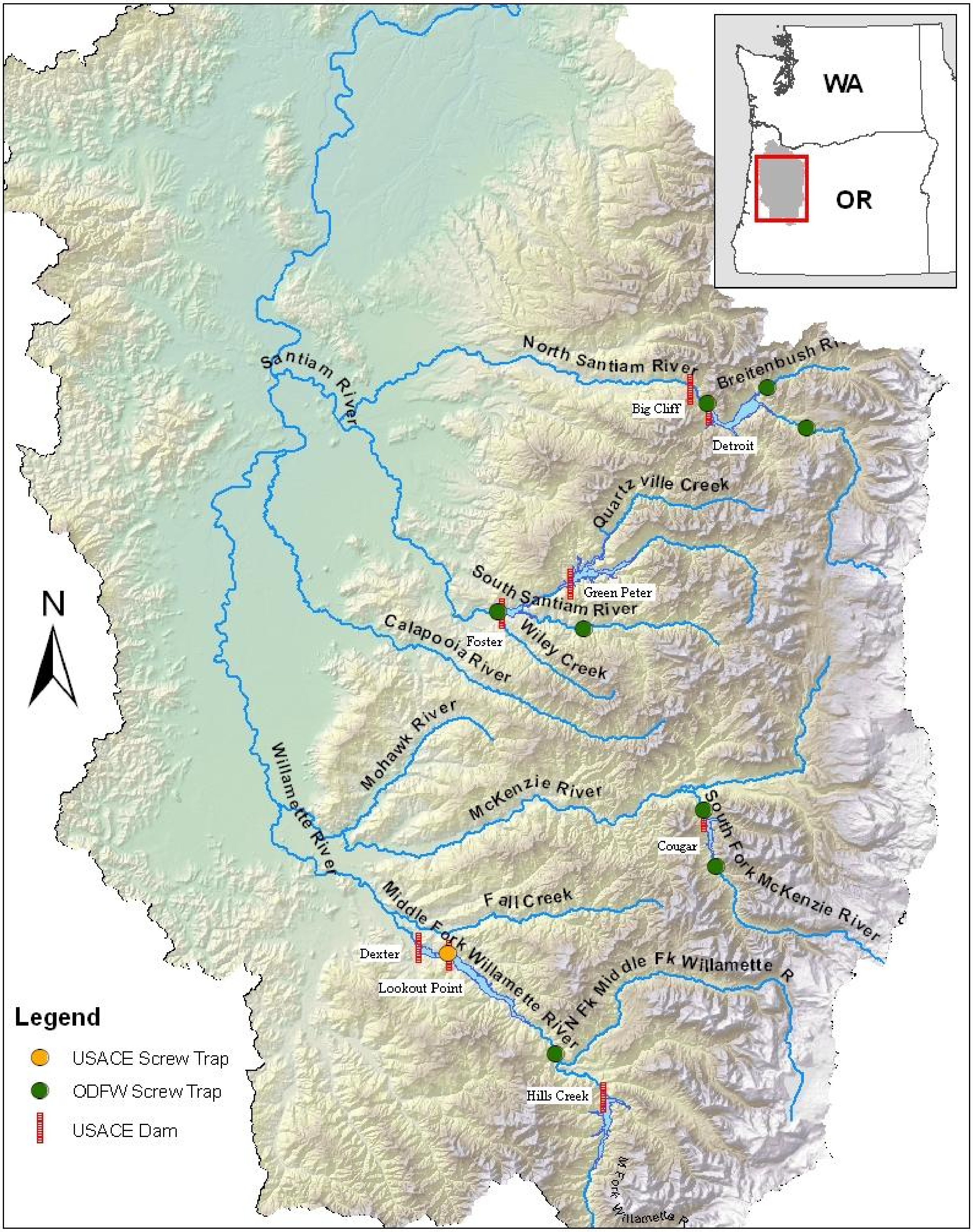

Figure 1. Locations of rotary screw traps operated by ODFW and USACE above and below Willamette Valley Project dams, 2011.

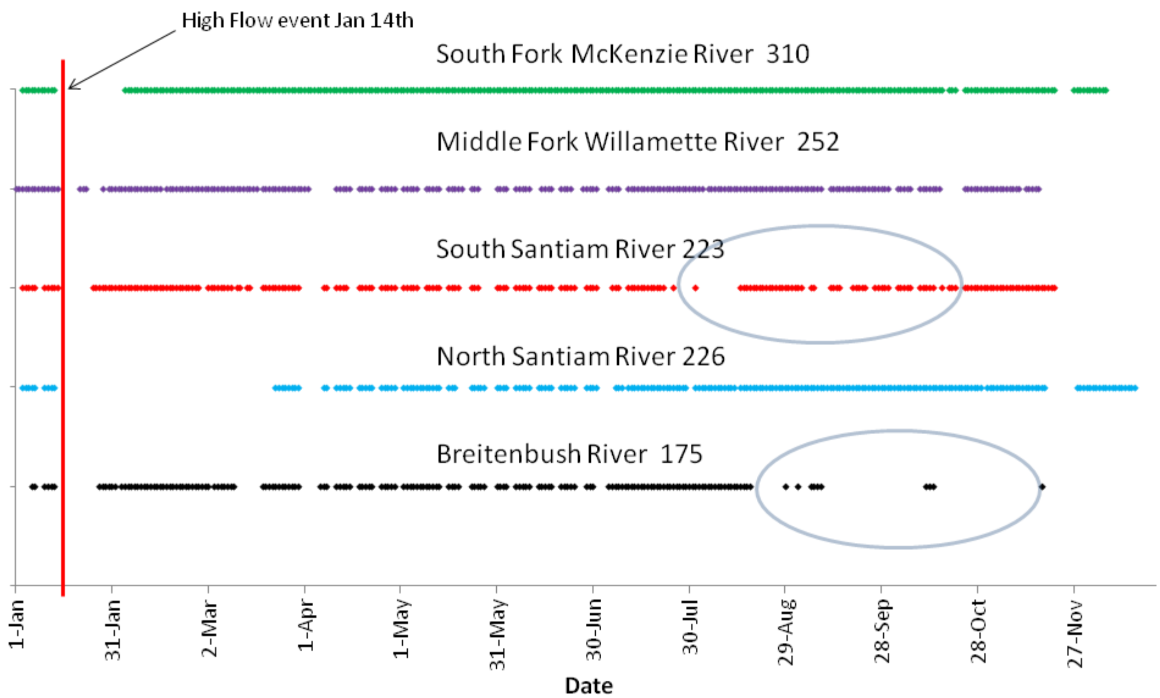

Figure 2. Screw trap operation summary for traps upstream of Willamette Valley reservoirs, 2011. Each colored dot represents one day of fishing; numbers are the number of days the trap was running based on a 365-day calendar year. Circled areas indicate the occurrence of low flows that were inadequate to spin the trap, resulting in intermittent operation.

Abundance Estimates of Outmigrating Chinook Salmon

Capture efficiency was calculated weekly for each species and age class (based on fork length) by marking fish from each species and age-class category (we used PIT tags, a small clip from the caudal lobe or Bismarck brown dye), and releasing the marked fish upstream approximately 500 m from the trap. Subsequent recaptures of marked fish were recorded. We calculated weekly abundance estimates for out-migrants by expanding trap catches using the following equations:

$N_m = c / e_m$
and
$e_m = r / m$,

where:

N_m = weekly estimated out-migrants
c = number of fish captured
e_m = measured weekly trap efficiency
r = number of recaptured marked fish
m = number of marked fish released

We calculated abundance estimates for sub-basins when we had sufficient trap efficiency estimates during the period of peak migration. We designated the period of peak migration as the inner quartile range of raw catch data for the season (between 25th and 75th percentile). Trap efficiency estimates were considered sufficient if more than five marked fish were recaptured per week for at least half of the weeks during the peak migration period. Weekly abundance estimates were summed for season totals. During weeks when recaptures were infrequent (< five recaptures/week), recapture totals for subsequent weeks were pooled to obtain at least five recaptures. If these criteria were not met for a particular sub-basin, the actual number of juvenile Chinook salmon captured was reported. Migrant abundance for periods when traps were stopped due to high flows or debris were estimated using the number of fish captured and the trap efficiency calculations for the weeks before and after the 'event'.

A bootstrap procedure was used to estimate the variance and construct 95% confidence intervals for each abundance estimate (Thedinga et al. 1994; 1000 iterations used for each calculation). This procedure uses trap efficiency as one parameter in the calculation of variance. A weighted value for trap efficiency was used to calculate confidence intervals. Each weekly estimate of trap efficiency was weighted based on the proportion of total estimated migrants that each weekly estimate of migrants represented, using the equation:

$e_w = e_m * (N_m / N_t)$,

where:

e_w = weighted weekly trap efficiency
e_m = measured weekly trap efficiency
N_m = weekly estimated migrants
N_t = season total migrants.

The sum of the weighted trap efficiencies was used in the confidence interval calculations.

Results and Discussion

Monitoring Infrastructure

All upstream rotary screw trapping sites remained consistent with the previous 2010 sampling locations (Table 1). We maintained long-term easement agreements with private landowners for the South Santiam and North Santiam trapping sites. All other sites were located on U.S. Forest Service (USFS) property that required limited duration Special Use Permits.

The Breitenbush trap was located on USFS property directly upstream of the USGS gauging station (station 14179000) and was approximately 0.5 km from the head of Detroit Reservoir at full pool. The North Santiam trap was located on private property directly downstream of Coopers Ridge Road Bridge and was approximately 5.8 km upstream of Detroit Reservoir when at full pool. The South Santiam trap was also located on private property near the town of Cascadia and was approximately 10 km upstream of Foster Reservoir at full pool. The South Fork McKenzie trap was located just downstream from the USGS gauging station (station

14159200) and was approximately 1 km upstream of Cougar Reservoir. The Middle Fork Willamette trap was located downstream of the town of Westfir, near the USFS seed orchard, approximately 5 km upstream of Lookout Point Reservoir.

We developed two additional trapping sites in 2011 below Detroit and Foster dams. The 2.4 m diameter trap below Detroit Dam was located approximately 579 m below the dam near the lower end of the boat restricted zone (BRZ). This trapping location allowed us to capture fish exiting through all of the possible passage routes through the dam. Below Foster Dam, we installed a 2.4 m diameter trap in the tailrace of the turbine discharge that was unable to capture fish exiting the reservoir via the spillways. We are currently working with USACE engineers to design a safe and structurally sound system to capture fish on the spillway side of the dam. Below Cougar Dam, we used pre-existing screw trapping infrastructure that was previously developed for monitoring fish passage at this site. At Cougar Dam the regulating outlet (RO) and turbine tailrace empty into two separate channels which merge approximately 100 m downstream of the base of the dam. Four traps were positioned below Cougar Dam (two 2.4 m diameter traps in the turbine tailrace, two 1.5 m diameter traps in the RO channel) enabling us to differentiate between fish captured in each channel. The 2.4 m trap located below Lookout Point Dam was operated by USACE personnel and is located approximately 260 m downstream of the base of the dam.

Table 1. Installation dates and location of rotary screw traps above and below upper Willamette project reservoirs 2011. River kilometer (rkm) refers to the distance from the specified location to the confluence with the Columbia River. UTM coordinates expressed as NAD 83 datum.

Trap Location - Upstream of Reservoir	Installation date	rkm	UTM (10T)
Breitenbush	January 6[a]	286	0568785 4955753
North Santiam	January 3	292	0575240 4949260
South Santiam	January 3	271	0539897 4915479
South Fork McKenzie	January 3	395	0562654 4877522
Middle Fork Willamette	January 1	358	0537699 4846035
Trap Location - Below Dam	**Installation date**	**RKM**	**UTM (10T)**
Detroit	April 4	271	0558956 4952722
Foster	July 26[b]	253	0526128 4917989
Cougar	January 1	385	0560486 4886873
Lookout Point	January 3	333	0519724 4862480

[a] Trap was not operational due to low stream flows beginning September 9 – removal in December.
[b] Trap installation was delayed due to large numbers of adult spring Chinook salmon and summer steelhead milling below the dam.

Juvenile Salmonid Migration Timing and Size

Fry (subyearlings <50 mm) were the predominant migrants caught at trap sites located upstream of reservoirs with peak migration varying as much as two months between sub-basins. Few subyearlings were collected from mid-June through the end of December at any of the trap sites, further suggesting that the majority of individuals migrate into WVP reservoirs as fry early in the spring.

At trap sites below project dams, the greatest catch occurred during late fall/early winter during reservoir drawdown and were comprised mainly of subyearlings. The exception to this was below Lookout Point Dam where the greatest catch occurred May through July and was associated with surface spill events during this period.

North Santiam River- We operated the North Santiam trap upstream of Detroit Reservoir from January 3 through December 3, 2011. A high flow event in mid-January damaged the trap and it was non-operable for 68 days (January 14 – March 23) during repairs and re-installation. The trap fished for 226 d in 2011, and captured 4,255 Chinook salmon subyearlings and 27 yearlings.

The run timing and size of subyearlings in the North Santiam trap were similar to subyearlings observed in the South Fork McKenzie River. The peak migration was from April through June (Figure 3) with a median migration date of May 6. Most subyearlings entering Detroit Reservoir from April through June were fry averaging 35 mm FL. The size range for subyearlings caught throughout the trapping season was 29-136 mm FL. Fish that were captured in June upstream of the reservoir showed greater variation in fork length (Figure 4), which suggests that some subyearlings may reside in the river above the reservoir for a longer duration before migrating when compared to populations from other sub-basins.

There was an extended period of migration for fry-size fish captured in the trap from mid-March through June, suggesting an extended period of fry emergence in the North Santiam. This was likely the result of both the timing of egg deposition which can range from late August to October (Cannon et al. 2011) as well as variation in stream temperatures among areas where redds were located. Most redds were located in the areas above and below the Horn Creek confluence and in Horn Creek itself (Cannon et al. 2011). Horn Creek and Marion Creek both maintain warmer temperature profiles throughout the winter when eggs are incubating compared to the mainstem North Santiam River (G. Grenbemer, ODFW, personal communication). This results in faster development and earlier fry emergence from redds deposited in these tributaries.

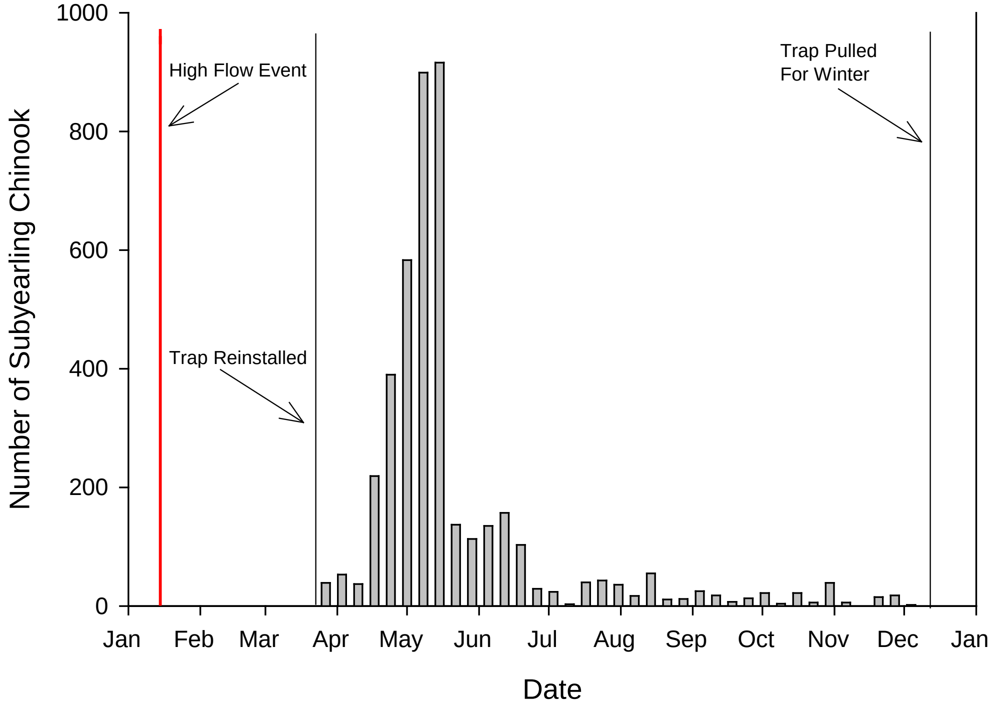

Figure 3. Weekly abundance of subyearling spring Chinook salmon captured at the North Santiam trap above Detroit Reservoir, 2011.

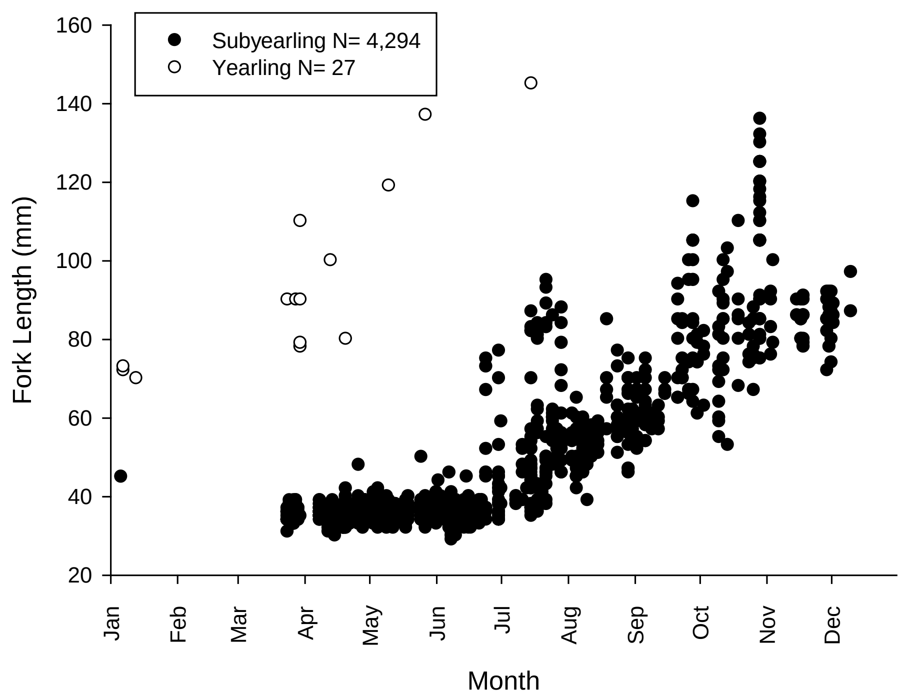

Figure 4. Scatter plot depicting size of juvenile Chinook salmon captured at the North Santiam trap upstream of Detroit Reservoir on a temporal scale, 2011.

Breitenbush River- We operated the Breitenbush trap upstream of Detroit Reservoir from January 6 through November 19, 2011. The trap was pulled (not fishing) between January 14 – 27 due to high flows, and again for one week in early March. In addition, the trap was only operable intermittently in late summer and through the winter due to low flows (Figure 2).

The trap fished for 175 d in 2011 and captured 1,036 Chinook salmon subyearlings and three yearlings. The peak of the fry migration appeared to be from February through April, with a median migration date of March 8 (Figure 5). This was nearly two months earlier than the median migration date in the North Santiam River. Spawn timing was similar between the Breitenbush and the North Santiam rivers (Cannon et al. 2011), so this difference in emigration was likely due to temperature differences between the rivers. Preliminary data from temperature loggers indicate the Breitenbush is warmer on average than the North Santiam in areas where salmon eggs are incubating.

The size range for subyearlings captured at the Breitenbush trap was 30-57 mm FL (Figure 6). Only 27 fish were captured after May 1, and the last fish was captured in the Breitenbush trap on August 3.

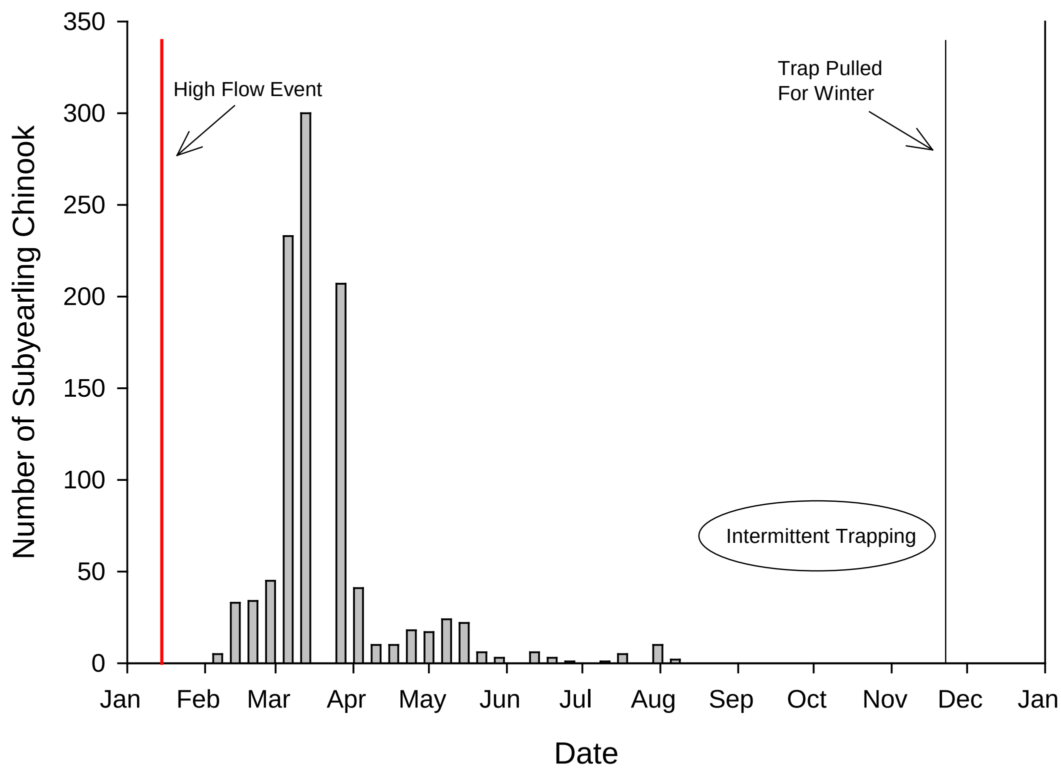

Figure 5. Weekly abundance of subyearling spring Chinook salmon captured at the Breitenbush trap upstream of Detroit Reservoir, 2011.

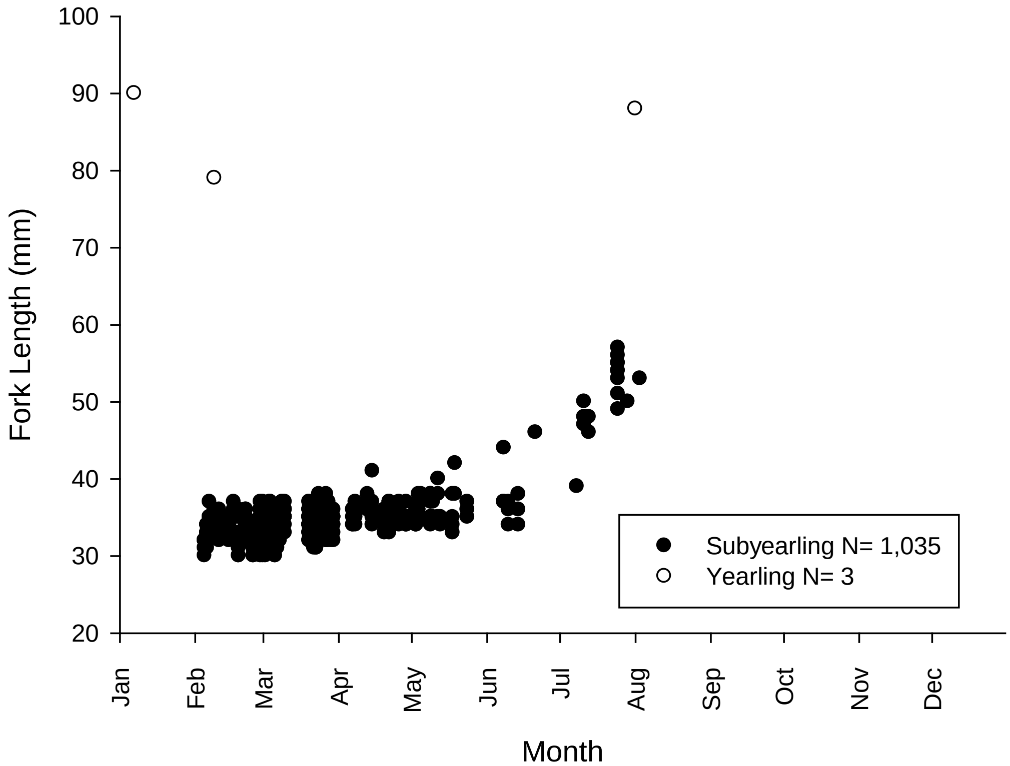

Figure 6. Scatter plot depicting size of juvenile Chinook salmon captured at the Breitenbush trap upstream of Detroit Reservoir on a temporal scale, 2011.

Below Detroit Dam- We installed a 2.4-m diameter rotary screw trap downstream of Detroit Dam on April 4 and operated it through December 30, 2011. The trap site was located at the bridge crossing that designates the lower end of the boat restricted zone and the deadline for fishing between the Detroit Dam tailrace and Big Cliff Reservoir. Water levels at this site were highly variable, making trap operation difficult. There were instances when Big Cliff Reservoir backed up to the trap site, resulting in inadequate flow to operate the trap. In other instances, the reservoir level fluctuated up or down approximately 2 m between trap checks, leaving the trap partially perched on bedrock or otherwise compromising fishing ability. Due to the dynamic reservoir elevations at the site, the trap only operated 67% (181/272) of the days that were available for fishing, resulting in limited catch information.

We captured 174 unmarked Chinook salmon, 205 hatchery Chinook salmon, and 218 kokanee *O. nerka* at this trap in 2011. The overall percent mortality for each of these species recovered from the trap was 60%, 43%, and 88% respectively. The hatchery Chinook salmon originated from an outplant of approximately 140,000 fingerlings into Detroit Reservoir by ODFW in late July 2011. Trap catch also included incidental species such as mysid shrimp *Mysis relicta,* pumpkinseed *Lepomis gibbosus*, and rainbow trout *O. mykiss*. Nearly all of the juvenile Chinook salmon that we collected below the dam (98%) were captured between August and December (Figure 7). This was similar to the results from screw trapping data collected in 2001 below Detroit Dam by ODFW. However, in 2001 the trap was only operational between January 3 – May 23 and then again October 23 – December 30 and showed that very few juvenile Chinook salmon were exiting Detroit Reservoir in the spring, and the peak migration was in the fall and winter months (Figure 8).

Another important difference between 2001 and 2011 was that no spill occurred at Detroit Dam during the summer of 2001. Beginning in 2007, summer spill operations have been used to control downstream temperatures. At our trap site in 2011, we caught Chinook salmon during August and September (Figure 7). Whether this summer dam passage has always occurred through the turbine discharge or was associated with the spill is unclear. For instance, during September 10 – 29, approximately 33% of dam discharge was spill and we captured 69 Chinook salmon over 23 d of trap operation, or ~3 fish/day. However, from October 12 – 20, all discharge was through the turbines and we captured 43 Chinook salmon over eight days of trap operation, or ~5 fish/day. With continued trap operation at this site, we hope to gather more information to help understand dam passage associated with different operational flows and reservoir operations.

The size of juvenile Chinook salmon captured in the trap below Detroit was similar to the size of juveniles collected in the reservoir but much larger than juveniles entering the reservoir during the same period (Figure 9). By November, the average size of juvenile Chinook salmon exiting Detroit Reservoir was 170 mm FL, whereas juveniles entering the reservoir averaged 85 mm FL.

While releasing juvenile Chinook salmon on December 6, 2011 below Detroit Dam to help determine trap efficiency (TE) estimates, we observed hundreds of rainbow trout that appeared to be attracted to the release site. The rainbow trout then became involved in what could be best described as a "feeding frenzy". It is unclear whether the trout were consuming juvenile Chinook without directly looking at diet contents. However, hundreds of trout feeding on fish passing through Detroit Dam could contribute to juvenile Chinook salmon mortality in addition to direct mortality incurred by the dam itself. During the December 2011 TE release the 200 fish (100 live, 100 dead) released averaged 142 mm (range 115-165) fork length, while Chinook salmon passing through the dam in December averaged 174 mm (n= 45, range 137-200 mm). On December 13-14 we caught nine hatchery rainbow trout averaging 444 mm in length while hook and line sampling below the dam. Diet samples collected from these trout contained primarily mysid shrimp and no identifiable Chinook bones. However, these days coincided with a period of low Chinook trap catch.

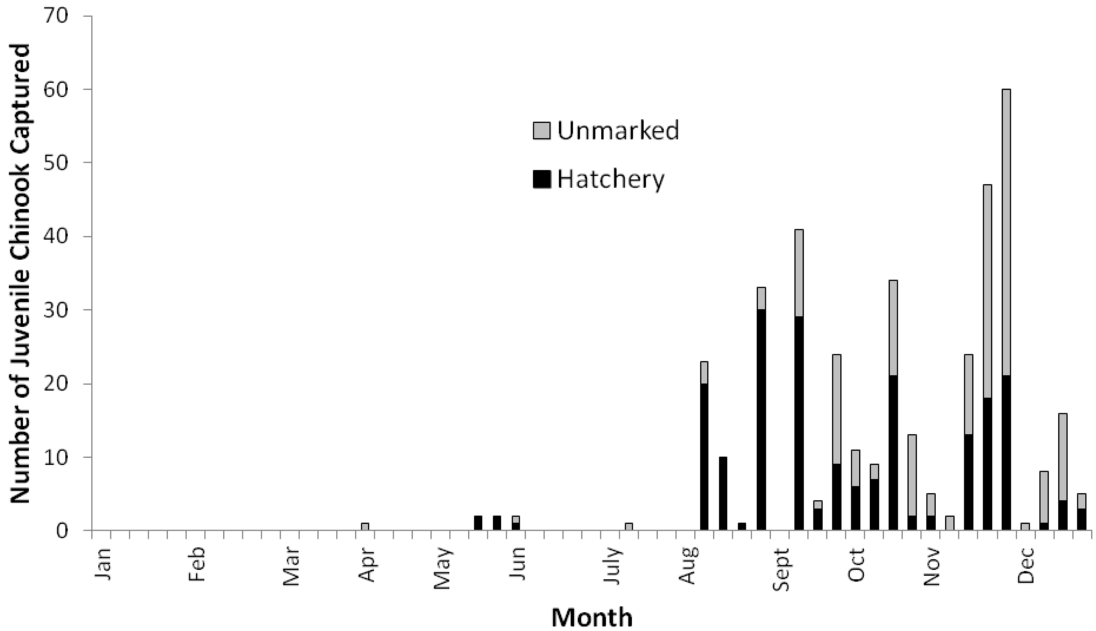

Figure 7. Total number of unmarked and hatchery Chinook salmon (subyearling and yearlings) captured in the rotary screw trap below Detroit Dam, 2011. The trap was installed on April 4.

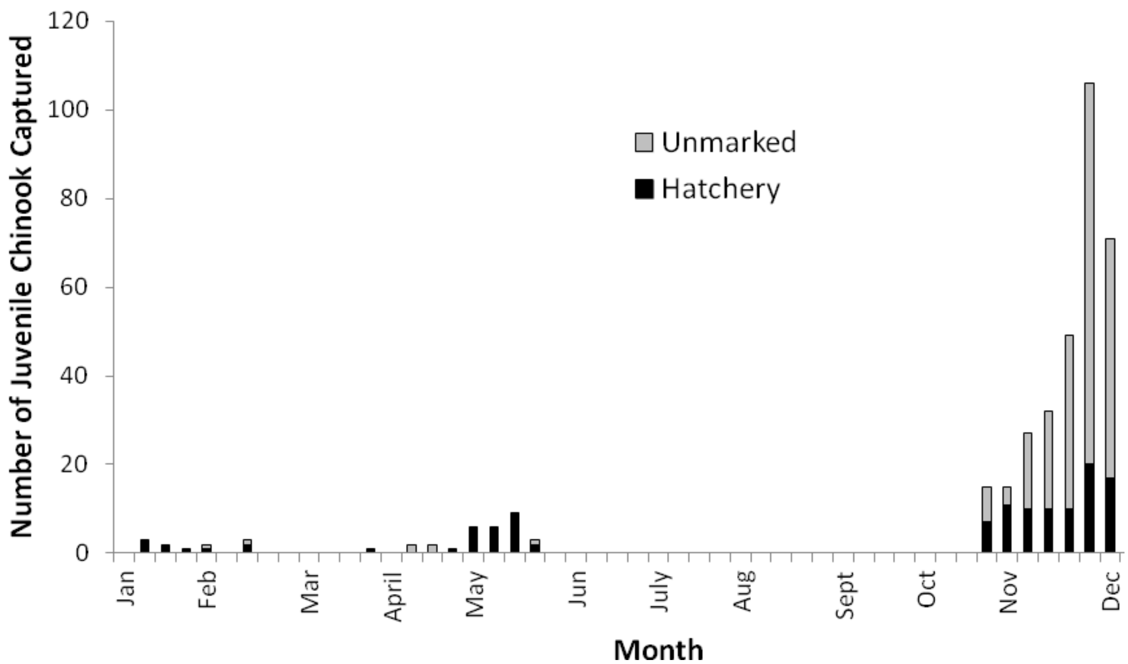

Figure 8. Juvenile Chinook salmon (subyearling and yearling) captured below Detroit Dam, 2001 (ODFW, unpublished data). The trap was not operated from June through the end of October, 2001.

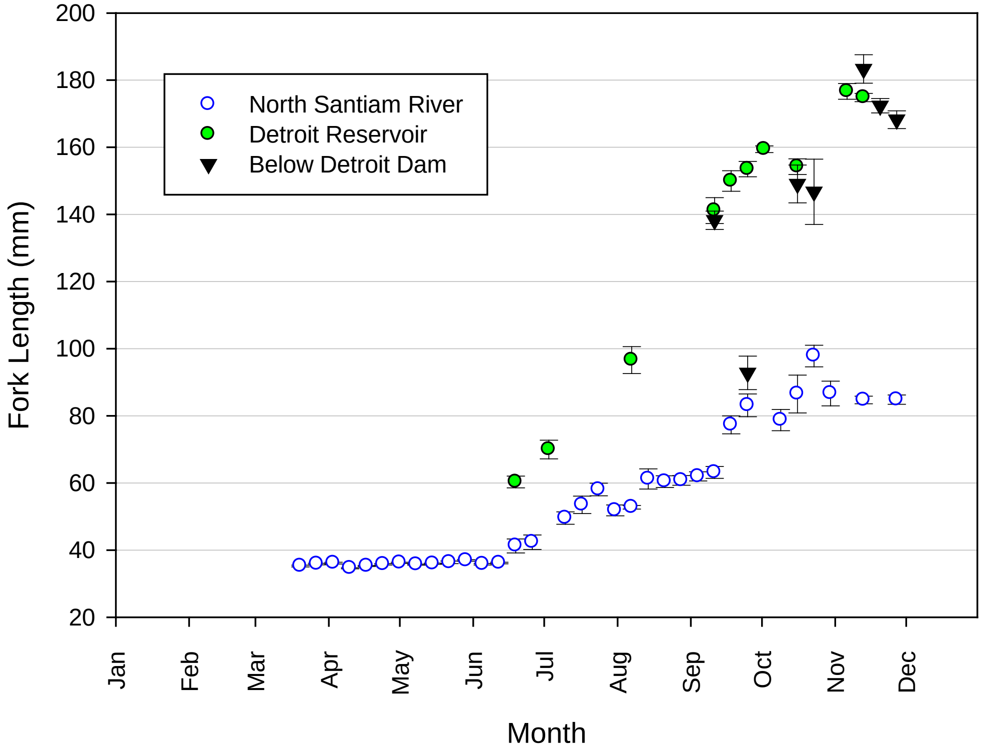

Figure 9. Comparison of the mean fork length of unmarked subyearlings captured in the North Santiam upstream of Detroit Reservoir, within Detroit Reservoir, and below Detroit Dam, 2011. Data were summarized by week; weeks where less than five fish were captured were excluded. Error bars represent the standard error.

South Santiam River Chinook Salmon- We operated the South Santiam trap upstream of Foster Reservoir from January 3 through November 20, 2011. The trap fished for 223 d. Catch rates for Chinook salmon were extremely low, as we captured only 14 Chinook salmon subyearlings (mean FL = 36 mm) and one yearling (117 mm FL) between January 4 and February 14, and none thereafter. Two of the subyearlings still had yolk sacs, suggesting they were scoured from redds during a flood event.

The South Santiam River experienced a flow event peaking at 11,800 ft^3/s (USGS gauging station 14158000 near Cascadia) on January 16, 2011 while many eggs and alevins were still in the gravel. This was the only substantial flow event recorded during the 2011 water year. The South Santiam River has a deeply incised channel, and a majority of the accessible spawning substrate is perched on bedrock. Therefore, this single high flow event likely scoured many redds and resulted, or greatly contributed to, a nearly complete year-class failure for the 2011 brood year. The last subyearling migrating past the trap was captured on January 14.

South Santiam River Winter Steelhead- In the South Santiam River, juvenile steelhead exist in sympatry with rainbow trout and cannot be distinguished from one another in the field. In this report both life histories will be referred to as *O. mykiss.* We captured 502 juvenile *O. mykiss* in the South Santiam trap in 2011. Based on fork lengths, there appeared to be at least two distinct year classes (Figure 10). The smallest fork length for the first *O. mykiss* captured was 25 mm, smaller than the smallest Chinook salmon fry that we captured in the South Santiam trap (34 mm). These subyearlings, presumably progeny from adult steelhead outplanted above Foster Reservoir began appearing as fry (<50 mm FL) in the trap early July with catch numbers peaking in late August and continuing through November (Figure 11). This subyearling cohort reached a maximum fork length of approximately 100 mm and comprised approximately 55% of the total steelhead catch by the end of the trapping season. Another year-class (presumably age 1) was also present with a size range from approximately 100 mm to 180 mm FL (Figure 10). It is unclear whether the observed fall migration above the reservoir continues through the reservoir and dam. Migration information from below the dam is incomplete for this cohort. We need to continue trapping above and below the dam this spring, along with PIT-tag marking, to provide information on the migration timing of juvenile steelhead.

We PIT tagged 206 *O. mykiss* >65 mm FL of unknown life history strategy at the South Santiam screw trap during August 15 – December 31. None of these fish were recaptured in our trap located below Foster Dam, detected downstream at Willamette Falls, or in the upper Columbia River estuary trawl detector operated by NOAA Fisheries. Future data collected from our continued trapping efforts upstream of Foster Reservoir, below Foster Dam, and in conjunction with the passive interrogation antenna at Willamette Falls should illuminate the migration behavior of winter steelhead from this sub-basin. It will also allow collection of information regarding the growth of resident fish that we might recapture in our screw trap upstream of the reservoir as they undergo in-stream migration associated with resident spawning behavior.

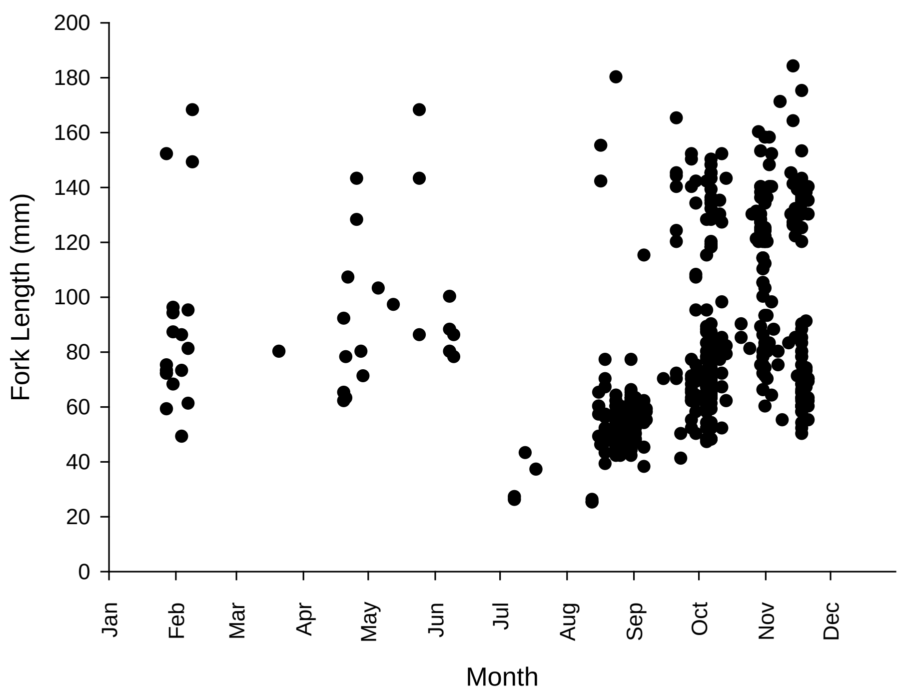

Figure 10. Fork lengths of *O. mykiss* (n = 502) caught in the South Santiam trap above Foster Reservoir, 2011.

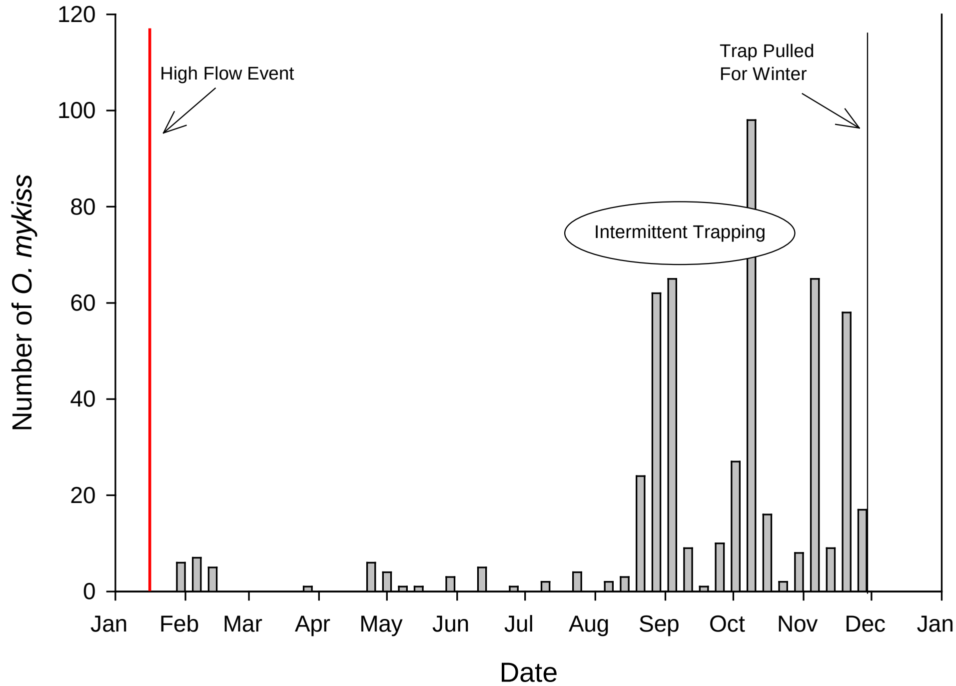

Figure 11. Weekly catch of juvenile *O. mykiss* at the South Santiam trap above Foster Reservoir, 2011. Catch includes subyearling and yearlings.

Below Foster Dam - The 2.4-m rotary screw trap was installed on July 26, 2011. We did not fish this trap until September 1 to avoid capture of the hundreds of adult salmon and steelhead that were milling below the dam. The Foster Dam trap operated 84% (102/121) of the days that were available for fishing. Trap catch included incidental species such as yellow perch *Perca flavescens*, kokanee, and *O. mykiss*. We only captured six subyearling Chinook salmon from November 1 through December 31, 2011, ranging in size from 110-180 mm FL. The low catch provided additional evidence that the egg-to-smolt recruitment for the 2010 brood year upstream of Foster Dam in the South Santiam River was poor. The first 2010 brood year subyearling was captured November 23 (FL = 180 mm), and the first subyearling for the 2011 brood year was captured only one month later, on December 23 (FL = 37 mm). We caught 27 *O. mykiss* from September 7 through December 10, 2011. Ninety-three percent of these fish ranged in size from 77-132 mm FL. The remaining 7% were likely resident adult rainbow trout with fork lengths ranging between 195-280 mm.

South Fork McKenzie River- We operated the South Fork McKenzie trap upstream of Cougar Reservoir from January 4 to November 18, 2011. The trap was non-operable for 18 d (January 14 – February 3) for repair and re-installation due to damage incurred from a high flow event. The trap fished for 310 d in 2011, and we captured 4,348 Chinook salmon subyearlings and 14 yearlings.

The greatest fry catch in the South Fork McKenzie occurred from April through June, with a median migration date of May 16 (Figure 12). The distinct migration of subyearlings in early spring at this trap site was consistent with what we have previously observed, and others have reported (Zymonas et al. 2012 *in prep*; Monzyk et al. 2011; Bureau of Commercial Fisheries 1960). As with the North Santiam trap, there was an extended period of fry-size fish captured at this trap from February through June (Figure 13), indicating an extended window of fry emergence.

The size of subyearling Chinook salmon ranged from 27 to 99 mm FL, and the mean fork length from April through June was 35 mm, the size at which most of them would be entering the reservoir. A majority of the yearlings were caught from January through March, and the few yearlings caught later in the year were precocial males that were milting. Growth of the subyearling cohort upstream of the reservoir was not evident until the end of June (Figure 13). Growth in 2011 was slower than the previous year due to lower water temperatures (Appendix C; Figure C1). This had negative implications for tagging fish upstream of the reservoir. Minimum size for PIT tagging is 65 mm, and we begin PIT tagging when the average fork lengths of fish captured in the screw trap is 60 mm. The later in the season that we tag fish, the less fish that are available for tagging upstream of the reservoir due to downstream movement into the reservoir, and natural mortality. In 2011, this benchmark was not reached until five weeks later in the sampling than in 2010 (Appendix C; Figure C1).

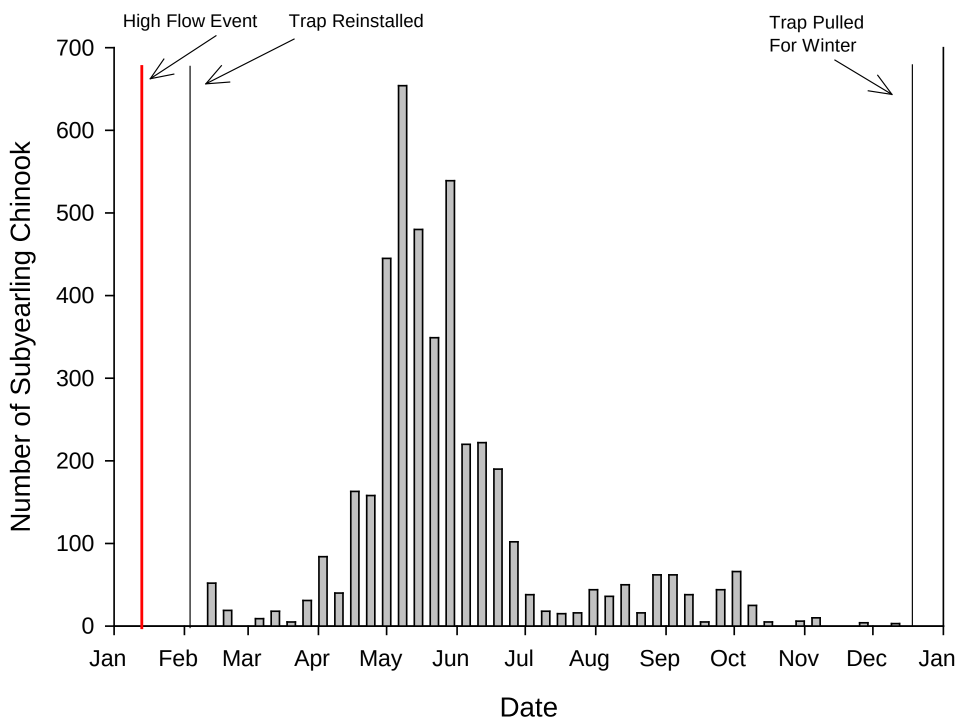

Figure 12. Weekly catch of subyearling spring Chinook salmon at the South Fork McKenzie trap above Cougar Reservoir, 2011.

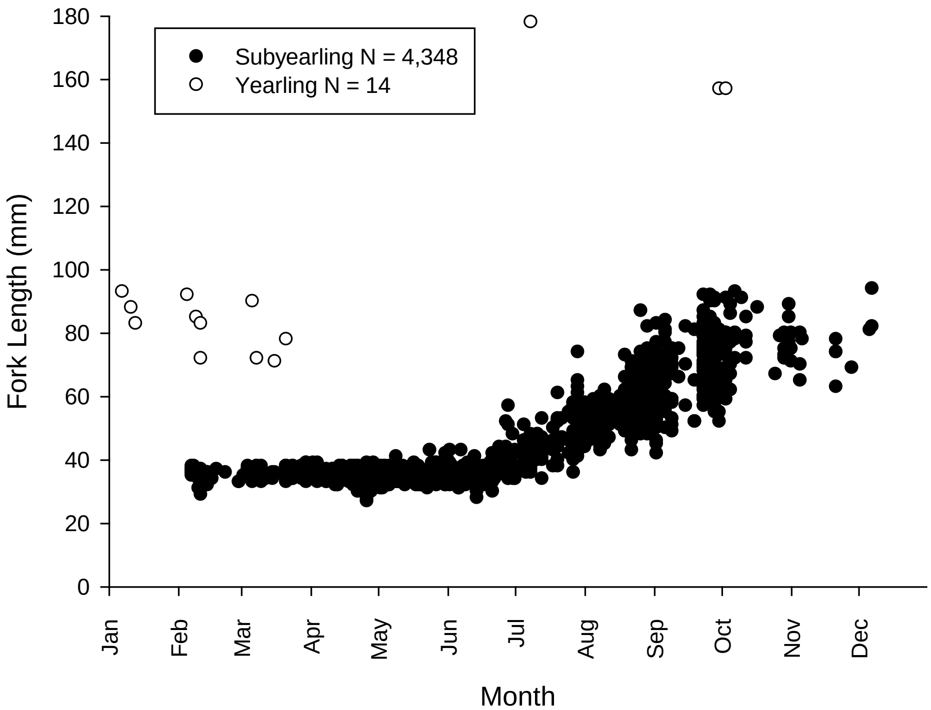

Figure 13. Fork length of subyearling and yearling Chinook salmon collected at the South Fork McKenzie trap above Cougar Reservoir, 2011.

Below Cougar Dam – We operated four rotary screw traps below Cougar Dam between January 3 and December 30, 2011. Juvenile salmonids exiting the reservoir have two passage route options by which they can navigate through Cougar Dam once they enter the temperature control tower: the turbine penstock (tailrace) or the regulating outlet (RO). At Cougar Dam, the RO and tailrace empty into two separate channels which merge approximately 100 m downstream of the base of the dam. As mentioned previously, our traps were positioned in each channel, which enabled us to differentiate catch between the two routes (two 2.4 m diameter traps in the turbine tailrace, two 1.5 m diameter traps in the regulating outlet).

The peak of the outmigration from Cougar Dam occurred between November and February (Figure 14), as has been observed by other researchers (Zymonas et al. 2012 *in prep*; Taylor 2000). Based on fork lengths, juveniles outmigrating during this period were comprised mostly of subyearlings, whereas juveniles outmigrating from January through July were comprised mainly of yearlings from the previous cohort (Figure 15). Although spring outmigrants were comprised mainly of yearlings, some older age-class fish (>200 mm FL) and subyearling fry (<50 mm FL) were captured during this period (Figure 15).

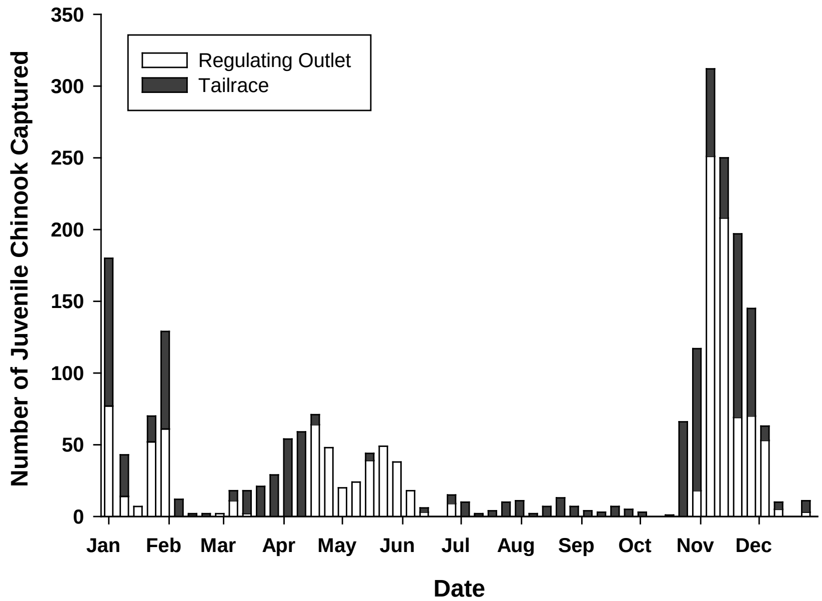

Figure 14. The total number of unmarked fish (subyearling and yearlings) captured below Cougar Dam in rotary screw traps in the tailrace and regulating outlet, 2011.

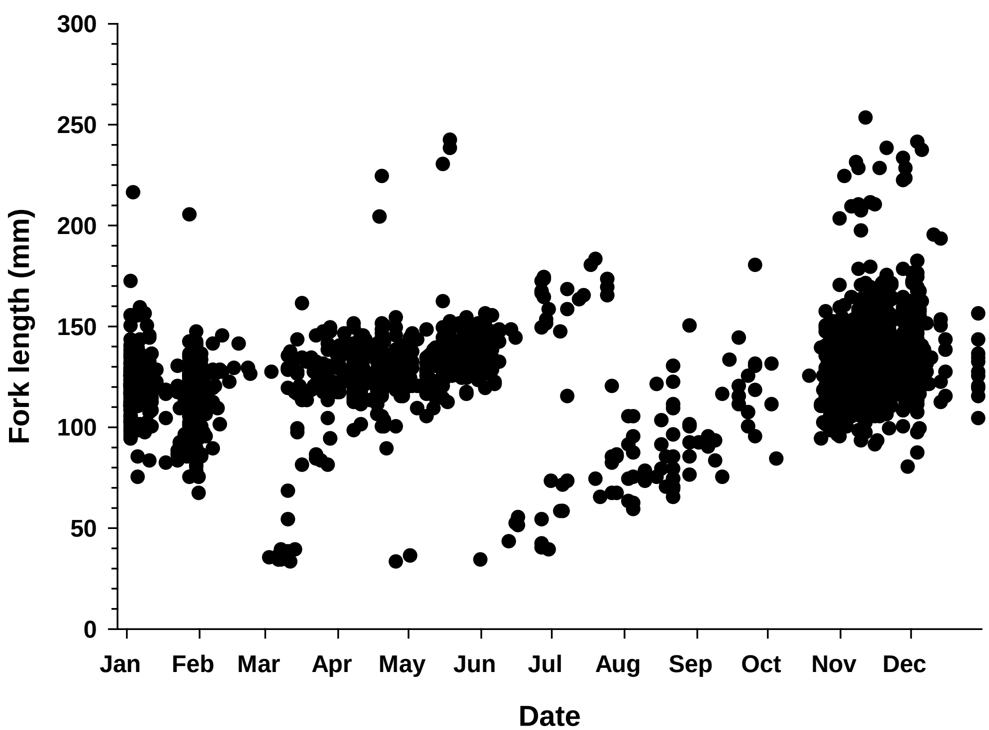

Figure 15. Relationship between fork length and date of capture for natural-origin juvenile Chinook salmon below Cougar Dam, 2011 (n = 2,239).

We captured 24 Chinook salmon fry (< 50 mm FL) in the traps below Cougar Dam. Seventeen fry were collected in the RO channel and one in the tailrace between March 7 and

April 16. From June 16 to June 30 we captured one fry in the RO channel and six in the tailrace. This suggested that fry were able to traverse the reservoir and survive passage through both routes, assuming that the captured fry emerged from redds upstream of Cougar Reservoir. Genetic samples collected from fry caught in previous years indicate that these fry were likely progeny from adults passed upstream of the reservoir. In 2009, 44 fry were sampled in the RO channel and genetic clips were taken. We received verification that all of these fry were progeny of adults passed upstream of the reservoir (Banks et al. 2012 *in prep*). Results from fry collected in 2010 and 2011 are currently being processed.

By November, the average size of juvenile Chinook salmon exiting Cougar Reservoir was 133 mm FL. Fish captured in the screw traps below the dam were larger than those captured in Cougar Reservoir using Oneida nets during the same period. In addition, juvenile Chinook salmon captured in Cougar Reservoir were larger than those captured in the South Fork McKenzie trap above the reservoir (Figure 16). This difference in size between fish caught in the reservoir and below the dam may be expected given the continued influx of smaller fish into the reservoir that were available for capture in Oneida traps (see Monzyk et al. 2012). However, it could also suggest some trapping bias toward collecting smaller fish when using surface oriented gear such as our Oneida traps in the reservoir. Oneida Lake traps were only effective at sampling the top 3 m of water within 33 m of the shoreline (Monzyk et al. 2012), and juvenile Chinook salmon move away from near-shore areas and occupy more pelagic habitats as they grow (Tabor et al. 2011).

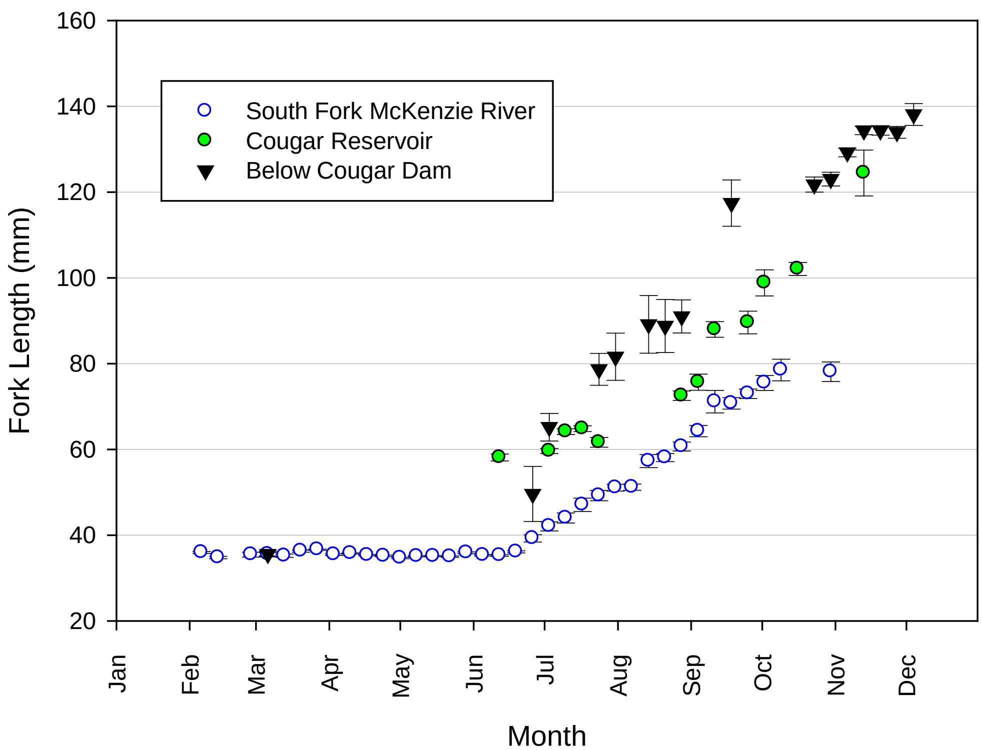

Figure 16. Mean fork length of unmarked subyearling Chinook salmon captured in the South Fork McKenzie River upstream of Cougar Reservoir, within Cougar Reservoir, and below Cougar Dam, 2011. Data were summarized by week; weeks when less than five fish were captured were excluded. Error bars represent the standard error.

Route Selection and fish size – Larger fish incur higher mortality when they pass through the turbines at WVP dams (Taylor 2000, Keefer et al. 2011, Zymonas et al. 2012 *in prep*). However, at Cougar Dam large fish may be deterred from entering the turbine penstock by a "trash rack" screen. The screen is a 10-ft x 10-ft panel that consists of 0.5-in x 2-in vertical bars on 2.5-in centers, which creates a 2-in vertical gap that fish must pass through to enter the penstock. The alternate route is through the RO, which is unscreened. We might expect to see a difference in fork length between fish exiting the dam between the two routes if the penstock screen acts as a deterrent to larger fish. To test this hypothesis we compared size of fish exiting the dam from each of the routes, for 2010 and 2011 separately, using Wilcoxon Rank Sum tests. Only data collected when both tailrace and RO traps were operating were used for comparison. Juvenile Chinook salmon captured in the tailrace traps during November and December 2011 were significantly smaller than those captured in the RO (P<0.001). Juveniles exiting the RO trap had a median fork length of 132 mm (25% 121 mm, 75% 146 mm), and those exiting the tailrace had a median length of 128 mm (25% 119 mm, 75% 140 mm). However, we did not detect a difference in size between routes in 2010 (P=0.861) when overall size of that cohort was smaller. Median fork length of juveniles exiting Cougar dam in November and December of 2010 were 115 mm (25% 107 mm, 75% 125 mm), significantly smaller than juveniles exiting the dam in 2011 with a median length of 130 mm (25% 120 mm, 75% 144 mm)(P<0.01). Overall, juvenile Chinook salmon exiting Cougar Dam were relatively small compared to those exiting other reservoirs (Figure 17). In addition, growth rates were dependent upon environmental rearing conditions (primarily temperature) within the reservoir, which were highly variable between years (Appendix C; Table C1). This suggests that route selection may affect survival of different cohorts to varying degrees.

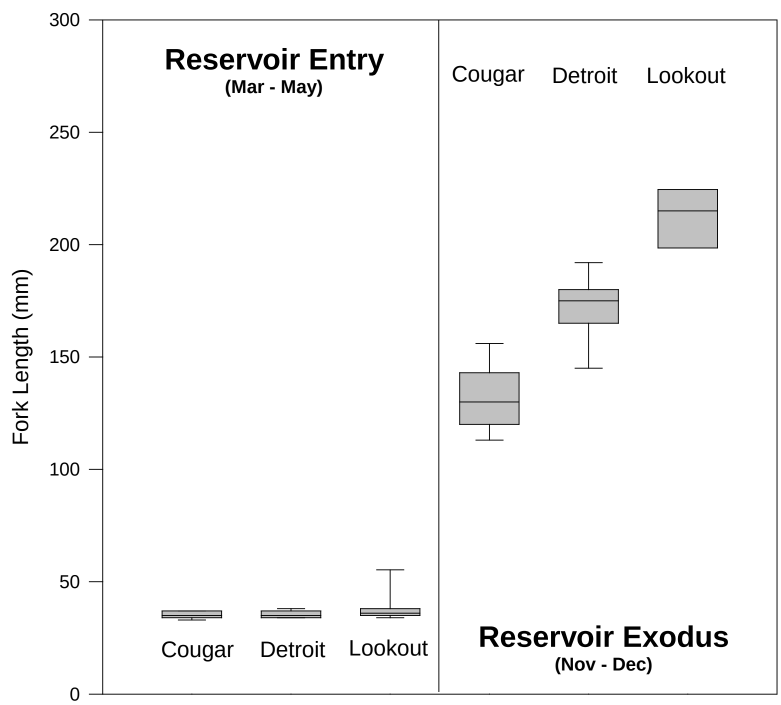

Figure 17. Box plots comparing growth (mm) for subyearling spring Chinook salmon among upper Willamette reservoirs upon entry and exit, 2011. Shaded boxes represent interquartile range, or the 25th and 75th percentile. Error bars represent the 5th and 95th percentile. Outliers were removed.

In November and December 2011, we captured 13 juvenile Chinook salmon in the RO that were >200 mm FL, and five >200 mm FL in the tailrace. It seems improbable that these large fish were passing through the penstock screen and exiting the dam from the tailrace. It is possible that they exited the dam through the RO channel and swam up the tailrace channel where they were subsequently captured in the screw trap located in the tailrace. To test this hypothesis we used data collected from antenna efficiency releases conducted between November 18, 2010 and January 28, 2011. We released 141 juvenile Chinook salmon with an average fork length of 150 mm into the RO channel below the dam during four separate release events. Of the 141 fish released, 35 (24.8%) were detected at the RO antenna located just upstream of the screw trap. Of the 35 that were detected in the RO, three (8.6%) were also detected at the tailrace antenna located just downstream of the screw trap in the tailrace channel. This suggests that it is possible for fish exiting the dam using one route to be detected in the outflow channel from the alternate route. This may be an important consideration when conducting route selection studies.

The route juvenile Chinook salmon select when passing through Cougar Dam appeared to be dependent on the amount of flow through each route. The USGS conducted a route selection study (November 8 - 17) using radio-tagged hatchery fish. During the experiment, discharge was partitioned approximately 50:50 through the turbines and RO. We observed 91% (386/426) of the total fish catch occurring in the RO traps during the experiment, similar to proportions of radio-tagged fish selecting the RO reported by the USGS (Beeman et al. 2012 *in prep*). Following the tagging study (November 18 - 30) flows were redirected so approximately 67% of the flow passed through the turbines and 33% went through the RO. During this time only 44% (178/402) of the total fish catch occurred in the RO traps. These data were not adjusted for trap efficiencies, which likely changed when flow ratios were altered between the two periods. Although some of the change in trap catch could possibly be explained by altered channel hydraulics and associated trap efficiencies, another possibility is that hydraulics within the temperature control tower changed with a slight increase in flow directed toward the turbines. These data warrant more detailed investigation (possibly with radio-tag studies) into route selection under different flow ratios through the RO and turbines.

<u>Direct Mortality</u> - There was some evidence to suggest greater mortality for fish exiting the RO than the tailrace under certain flow conditions. Dam discharge was directed exclusively through the tailrace from April 7 – 14 with a range of 500-1,000 ft^3/s. During this period we captured 105 juvenile Chinook salmon and observed 11% mortality. From April 15 – 22, a pulse of flow was directed out of the RO, with total overall dam discharge peaking at nearly 3,000 ft^3/s (RO 2,000, tailrace 800 ft^3/s). During this pulse period we captured 64 juvenile Chinook salmon in the RO channel and ten in the tailrace, with 30% and 10% respective mortality. In April and May (RO avg. flow 1000, tailrace avg. flow 510 ft^3/s) we observed 34% mortality in the RO (87/259) and 12% from the tailrace (14/120). Other researchers have also noted a higher percentage of dead fish captured in the RO trap than the tailrace (Taylor 2000, Zymonas et al. 2012 *in prep*). A potential confounding factor is that the cause of death for fish captured exiting each route is different, and the method of mortality could be correlated to the efficiency of the screw trap to collect the carcass. For example, if fish are killed passing through a turbine they may be cut in half, or their swim bladder could be punctured which would decrease buoyancy.

The carcass could then roll along the substrate and pass under the trap undetected. It should be noted that hydraulic patterns and discharge also affect screw trap efficiency for both dead and live fish, and these effects are highly variable and difficult to quantify.

Delayed Mortality - We PIT tagged 1,068 juvenile Chinook salmon >65 mm FL below Cougar dam beginning in February 2011 to investigate downstream detection rates on a temporal basis, and delayed mortality associated with route selection. Overall, detection rates at downstream sites were higher for fish released from the tailrace throughout the year (Appendix C; Table C2). To test route-associated delayed mortality we conducted a direct comparison between the RO and tailrace from November 18 - 29 (following the USGS route selection study). This period was the only opportunity where the number of fish captured on the same day was approximately ten in both the RO and the tailrace traps. We hypothesized that the number of tagged fish released on the same day (experiencing the same environmental conditions) would be detected downstream at fixed interrogation sites (Leaburg, Walterville, and Sullivan Plant) at the same rate regardless of the route they selected to exit the dam. Discharge from the dam remained consistent, around 1,650 ft^3/s throughout this time period (Tailrace 1,100, RO 550 ft^3/s). Downstream detection rates were higher for tailrace releases (P= 0.042, Z= -2.033 z-test for difference between independent proportions) (Appendix C; Table C3). These results suggest that delayed mortality may be higher for fish exiting the regulating outlet.

It is also possible that holding fish in the RO trap prior to tagging may have affected results by increasing fish exposure to supersaturated total dissolved gas levels, although fish did not exhibit many signs of gas bubble disease prior to tagging. In addition, Britton and Barko (2006) found that TDG levels in the RO channel at Cougar Dam ranged from 115 – 118% for flows between 400 and 1,200 ft^3/s, and for these TDG ranges a depth-compensated TDG of 110% can be achieved at the minimum depths of 51.8 cm and 82.3 cm, respectively. A review of TDGS literature conducted by McGrath et al. (2006) reports that, “short-term exposure to up to 120% TDGS does not produce significant effects on migratory juvenile or adult salmonids when compensating water depths are available.” In addition, Mesa et al. (2000) reported that Chinook salmon 133-150 mm FL held in 28 cm of water (approx 40 cm in a screw trap live box) at 120% saturation required 40 – 120 hrs before mortality reached 20% (LT_{20}). During the direct comparison of delayed mortality between routes, juvenile fish were held for a maximum of 24 hrs, but more likely 12 hrs or less as most fish exit the dam at night (Beeman et al. 2012 *in prep*; Zymonas et al. 2012 *in prep*) and traps were checked each morning. We do not believe that the increased delayed mortality in the RO during this time period can be attributed to the holding of the fish in the screw trap live box. Decreased numbers of downstream detections for fish exiting the RO were also observed by the USGS during their route selection study (Beeman et al. 2012 *in prep*), and those fish were not subjected to screw trap holding conditions. Results from both experiments were inconclusive but warrant further investigation considering our corroborating observations.

Middle Fork Willamette River- We operated the Middle Fork Willamette trap upstream of Lookout Point Reservoir from January 1 through November 17, 2011. The trap fished for 252 d, and captured 837 Chinook salmon subyearlings and 15 yearlings. The peak of the fry migration was January through June, and the median migration date was March 28 (Figure 18). The size range for subyearlings was 29-110 mm fork length. The high number of subyearlings captured near the beginning of January is presumably an artifact of increased flows that were pushing newly emerged fry downstream. The mean size of fry captured during this period was 34 mm FL.

Fish we captured in the Middle Fork Willamette trap upstream of the reservoir exhibited greater variation in fork length than any of the other trapping sites (Figure 19). Several factors may contribute to the prolonged subyearling migration timing, and large variation in size of migrants. First, the location of the trap in relation to where most of the adult spawning takes place, in the North Fork Middle Fork Willamette River (NFMF). The trap was located 58 km from the furthest known upstream spawning area, nearly twice the distance of any of the other traps in relation to upstream spawning areas. Second, some subyearlings may reside longer in the relatively high-quality rearing habitat present in the NFMF longer before migrating downstream. Finally, trap catch was confounded by juvenile Chinook salmon emigrating out of Hills Creek Reservoir. These variables, along with the higher temperatures, lend insight as to why fish captured in the Middle Fork Willamette were larger than their counterparts rearing in the other sub-basins (Figure 20). For example, during the first week of May the fry in the South Fork McKenzie River averaged 35 mm fork length (N=125, SE 0.15) and juveniles in the Middle Fork Willamette averaged 45 mm (N=90, SE 1.24).

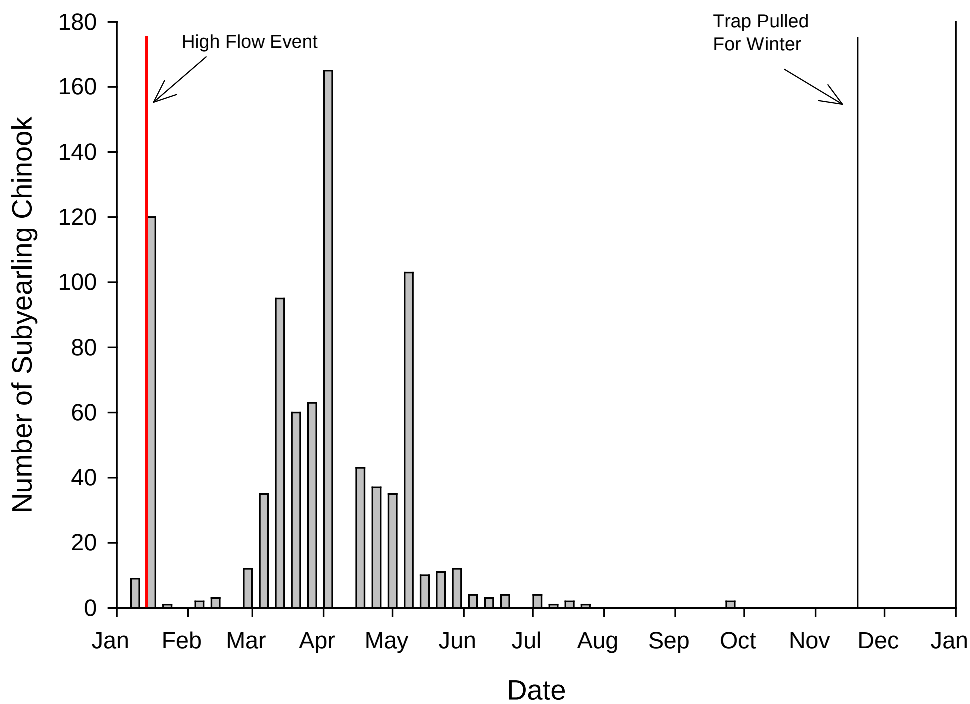

Figure 18. Weekly catch of subyearling spring Chinook salmon at the Middle Fork Willamette trap upstream of Lookout Point Reservoir, 2011.

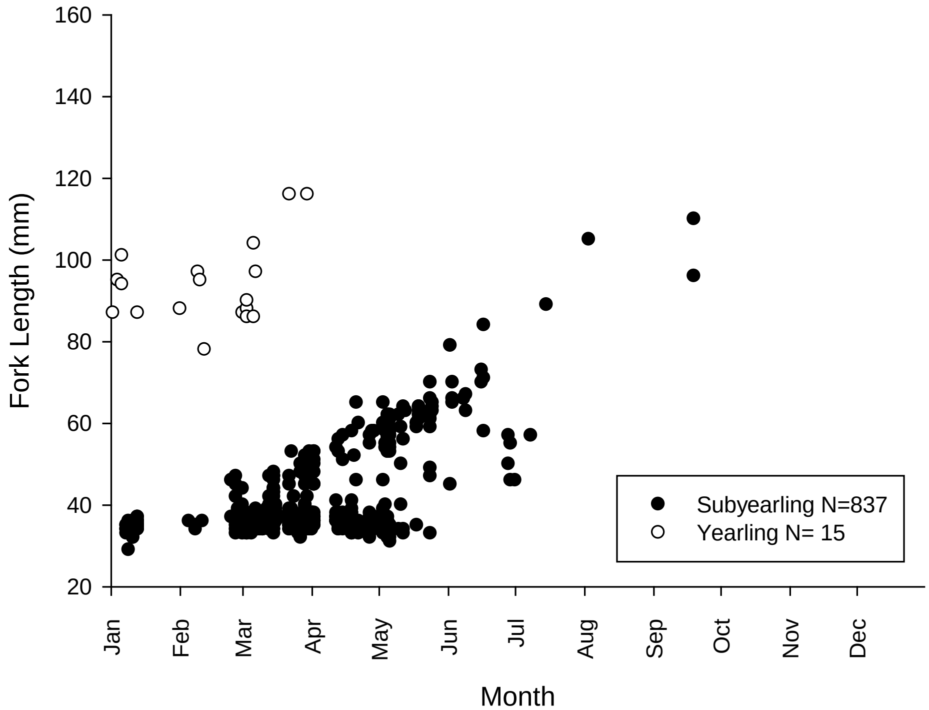

Figure 19. Fork length of subyearling and yearling Chinook salmon collected at the Middle Fork Willamette trap, 2011.

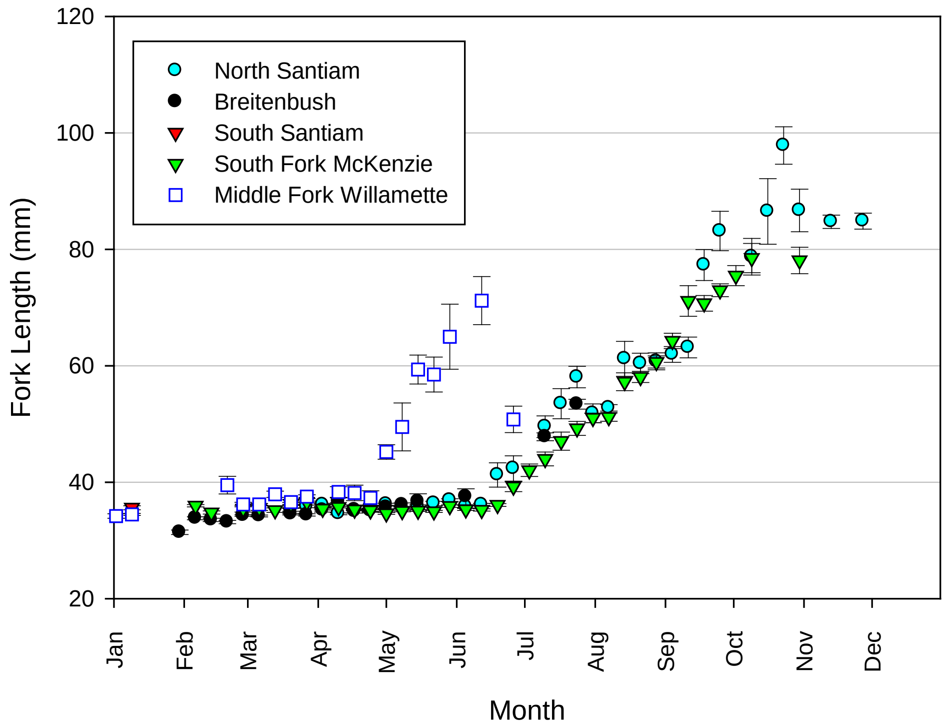

Figure 20. Comparison of growth for subyearling spring Chinook salmon at each upstream screw trap location, 2011. Data were summarized by week, excluding weeks when < 5 juveniles were captured. Error bars represent the standard error.

Below Lookout Point Dam- Personnel from the USACE operated two 2.4-m screw traps below Lookout Point Dam from January 4 to November 23, 2011. The traps captured 89 hatchery and 142 unmarked juvenile Chinook salmon (subyearling and yearling). Capture numbers were low compared to other traps located downstream of project reservoirs. However, the variety of species captured in this trap was greater than any of the other traps and included: northern pikeminnow *Ptychocheilus oregonensis*, bass *Micropterus* spp., rainbow trout, cutthroat trout *O. clarkii*, walleye *Sander vitreus*, crappie *Pomoxis* spp., sculpin *Cottus* spp., dace *Rhinichthys* spp., redside shiner *Richardsonius balteatus*, sucker *Catostomus* spp., and bullhead *Ameiurus* spp. Subyearling Chinook salmon in Lookout Point Reservoir grew fast and exceeded 200 mm FL by the end of the year (Figure 21), and those leaving Lookout Point Reservoir were larger than subyearlings exiting other upper Willamette reservoirs during November and December (Figure 17).

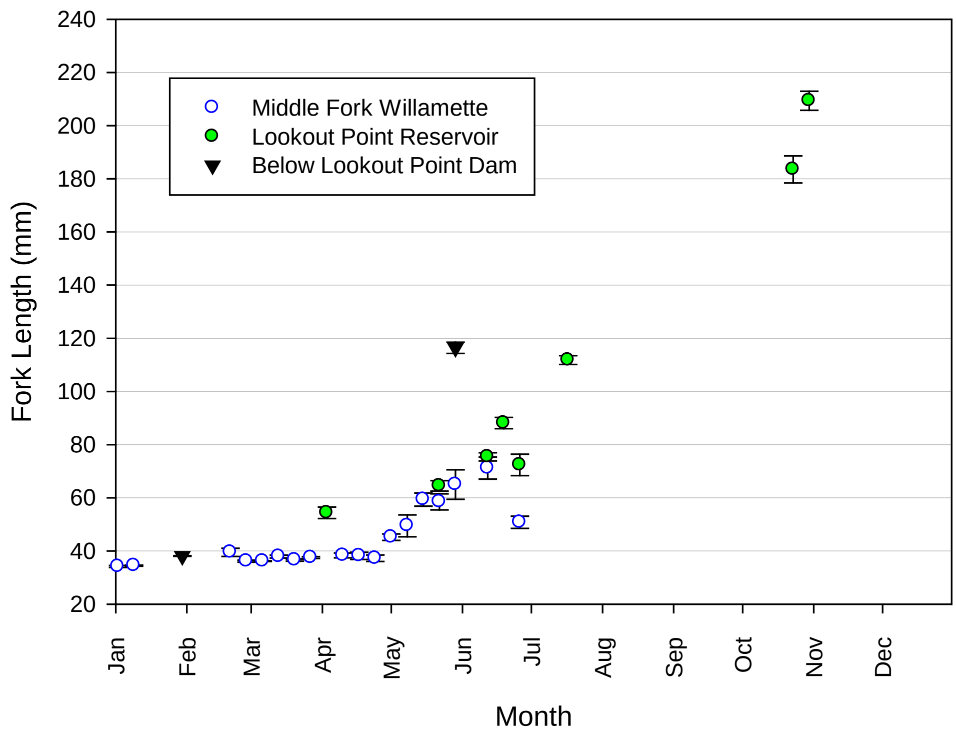

Figure 21. Mean fork length of unmarked Chinook salmon subyearlings captured in the Middle Fork Willamette River upstream of Lookout Point Reservoir, within Lookout Point Reservoir, and below Lookout Point Dam, 2011. Data were summarized by week; weeks when less than five fish were captured were excluded. Error bars represent the standard error.

Most fish captured from January through May were yearlings (based on fork length), although a few fry were captured in February. On May 19, approximately 200,000 coded-wire tagged juvenile hatchery Chinook salmon (subyearlings) were released along with 5,967 additional PIT tagged hatchery fish at the head of Lookout Point Reservoir by ODFW as part of a paired release study (Friesen et al. 2012 *in prep*). During May 19 - 22, just after the experimental fish were released, spillway discharge increased from 1,330 to 3,900 ft^3/s while flow directed through turbines decreased from 2,200 to 0 ft^3/s (Figure 22). This increased spillway discharge resulted in an increased number of Chinook salmon captured below the dam (particularly hatchery fish) in late May (Figure 23). The spillway continued to operate through the end of June, and for two weeks in July. Increased spill likely accounts for the pulse of fish leaving the reservoir from mid-May through June. Increased spill during summer months is non-typical of historical flow management regimes (Appendix D; Figure D1). Most juvenile Chinook salmon in the Middle Fork Willamette River exit Lookout Point Reservoir between November and February (Keefer et al. 2011). The November - February outmigration period was consistent with the data we have collected below dams in other upper Willamette sub-basins.

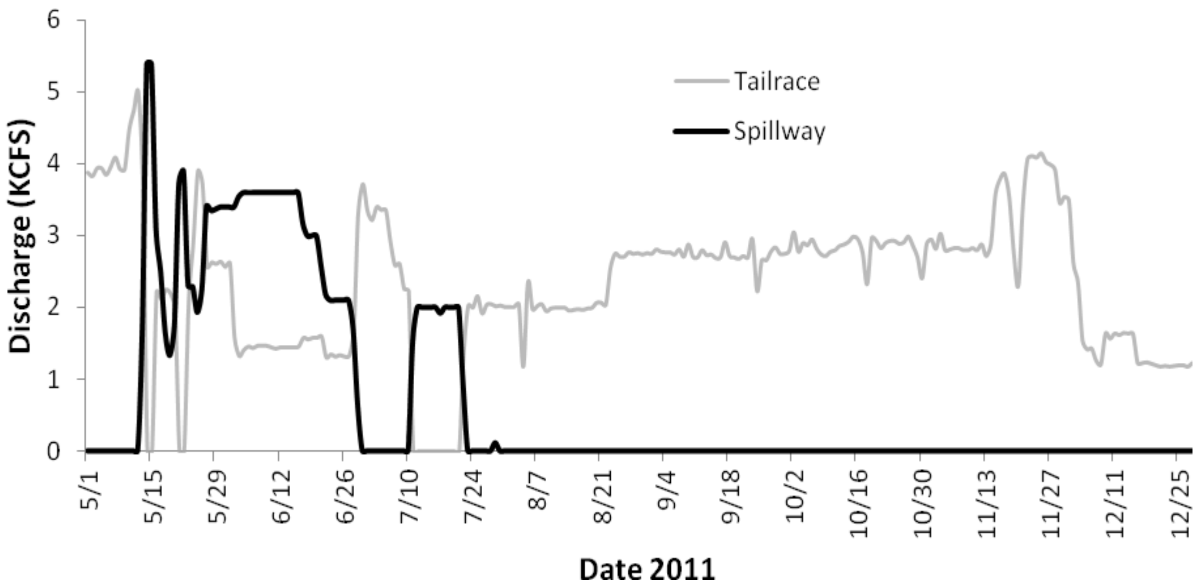

Figure 22. Discharge from the tailrace and spillway of Lookout Point Dam for May 1 – December 31, 2011 (data courtesy USACE data query website).

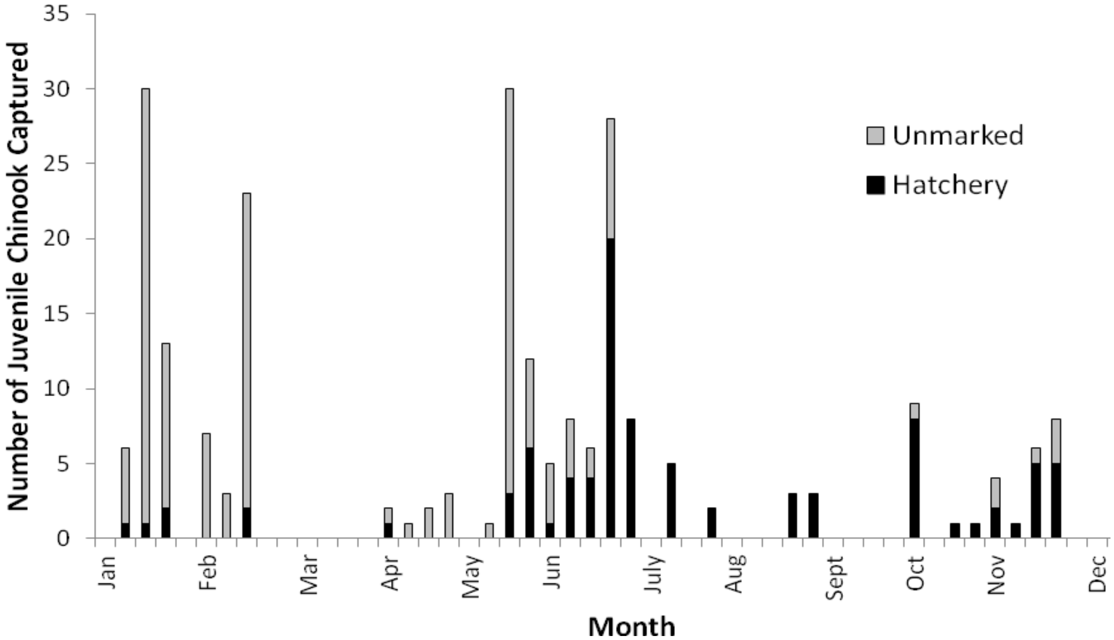

Figure 23. Total number of unmarked and hatchery Chinook salmon (subyearling and yearlings) captured in rotary screw traps below Lookout Point Dam, 2011.

Abundance Estimates of Outmigrants

Migrant abundance for periods when traps were stopped due to high flows or debris were estimated using the number of fish captured and the trap efficiency calculations before and after the 'event'. The amount of time a trap was stopped varied throughout the season and among traps (Figure 2).

The North Santiam trap upstream of Detroit Reservoir - Weekly trap efficiencies ranged from 0.8 to 1.9% with a weighted yearly TE of 1.2% in 2011. We estimated 587,960 (95% CI ± 193,708) subyearlings (2010 brood year) migrated out of the North Santiam River and into Detroit Reservoir between January and December 2011 (Figure 24). The vast majority of subyearlings (88%) moved into Detroit Reservoir as fry from April through June. A high flow event in mid-January damaged the trap and it was non-operable for 68 days (January 14 – March 23) during repairs and re-installation. The large variance surrounding the estimated number of migrants is the result of the low trap efficiency associated with this site.

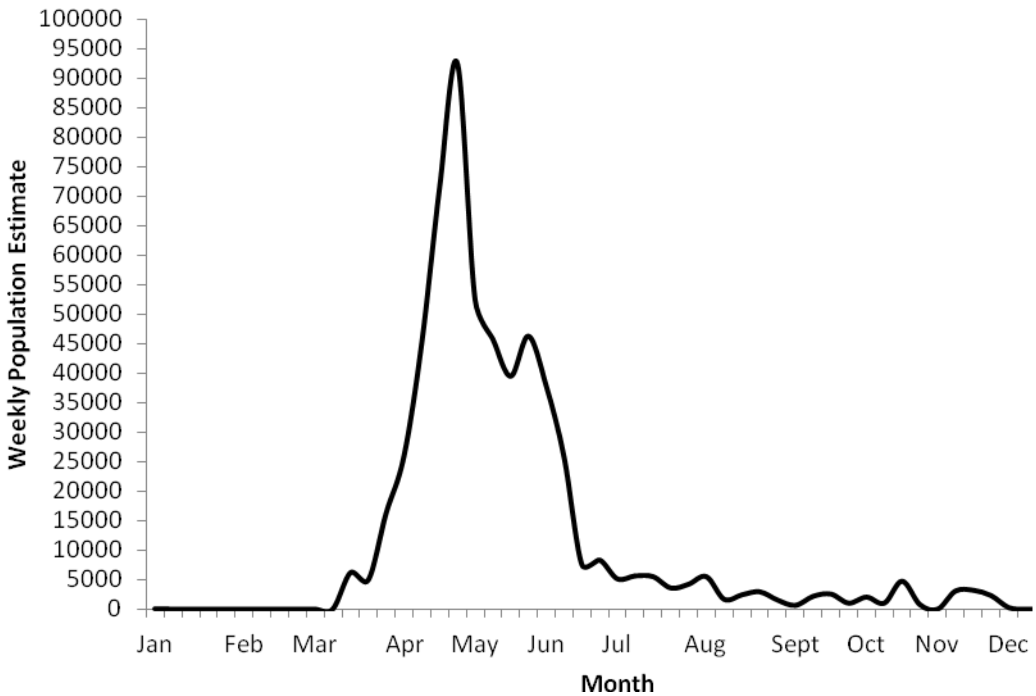

Figure 24. Weekly population estimates for subyearling spring Chinook salmon migrating past the North Santiam trap in 2011. The number of fish captured while the trap was non-operable (January 14 – March 23) was estimated using the number of fish captured before and after the high flow event.

The South Fork McKenzie trap upstream of Cougar Reservoir - Weekly trap efficiencies ranged from 1.5 to 23.5% with a weighted yearly TE of 2.9 % in 2011. We estimated 152,159 (95% CI ± 26,665) subyearlings migrated out of the South Fork McKenzie River and into Cougar Reservoir between January and December 2011 (Figure 25). The vast majority (90%) of subyearlings moved into Cougar Reservoir as fry from April through June. This estimate was much lower than the 2010 estimate of 685,723 (95% CI ± 72,519). Reduced number of females outplanted upstream of the reservoir and corresponding number of redds likely contributed to the reduced number of migrating subyearlings in 2011. In 2009, 629 females were outplanted upstream of Cougar Dam and 274 redds were observed (Cannon et al. 2010) (Appendix B; Table B1). In comparison, 320 females were outplanted and 190 redds were observed in 2010 (Cannon et al. 2011). In addition, extremely high flows (7,060 ft^3/s) occurred on January 16, 2011 while eggs for the 2010 brood year were still in the gravel, which likely decreased egg-to-fry survival. The number of redds observed during spawning ground surveys downstream of the South Fork McKenzie screw trap were less than five in 2010, and thus would not significantly affect the 2011 subyearling abundance estimate.

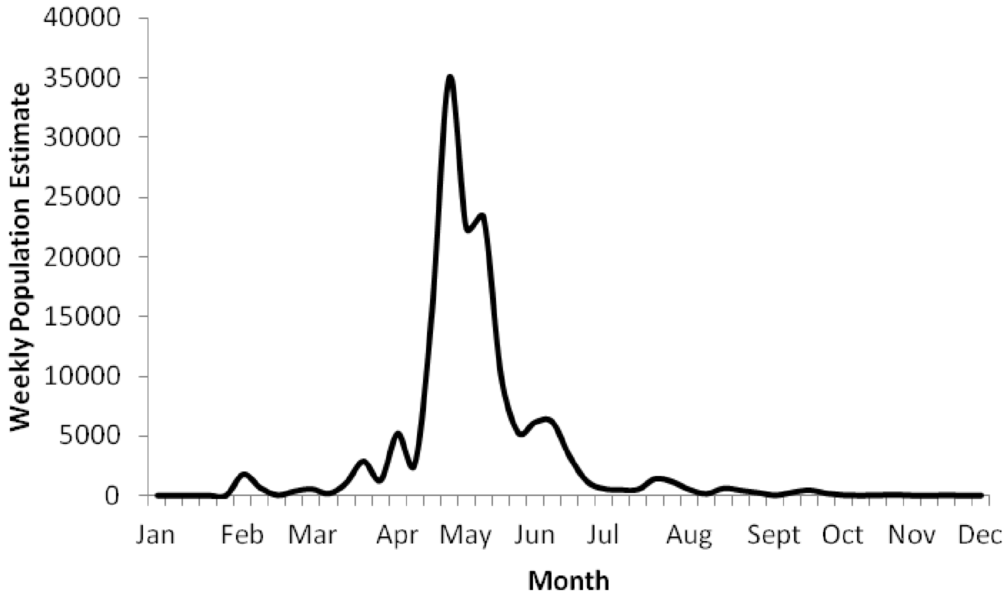

Figure 25. Weekly population estimates for subyearling spring Chinook salmon migrating past the South Fork McKenzie trap in 2011.

Recommended Future Directions

Our data illustrates that the subyearling year class was the prominent year class emigrating from streams and into WVP reservoirs. Although these fish grow larger and more quickly in the reservoirs, larger individuals also incur higher mortality when passing through turbines (Taylor 2000, Keefer et al. 2011, Zymonas et al. 2012 *in prep*). Reservoir-rearing juveniles are also exposed to predation by resident fishes and copepod infestations (Monzyk et al. 2012), though both risks have yet to be fully assessed. We suggest that a way to mitigate for risks associated with reservoir rearing would be a management strategy aimed at providing safe passage through reservoirs for this early life-history component.

Poor recruitment of juvenile Chinook salmon in the South Santiam River was observed for the 2010 brood year due to high flow at the crucial time when eggs and alevin were still in the gravel. If low survival persists in the South Santiam River, we suggest investigating the survival of juvenile Chinook salmon migrating through Green Peter Reservoir. If survival and passage through Green Peter Reservoir is deemed acceptable, then releasing adults directly into the Middle Santiam River may prove a better alternative than the current release site in the South Santiam. Although Buchanan et al. (1993) reported low survival of juvenile Chinook salmon migrating through Green Peter Reservoir due primarily to predation; we suggest that a more specific survival and passage study be conducted in this reservoir.

While releasing juvenile Chinook salmon below Detroit Dam to help determine trap efficiency estimates, we observed hundreds of large rainbow trout that may be feeding on juvenile Chinook after they pass through the dam. Predation directly below the dam could constitute a substantial risk to juvenile Chinook salmon below the dam. We plan to further investigate this situation during the upcoming field season.

We will continue to operate rotary screw traps at the same locations in 2012 with the exception of the trap below Detroit Dam. Due to unfavorable fishing conditions and low catch, we propose to move this trap closer to the tailrace of the dam. Continued monitoring at the other existing sites will provide a more complete picture of outmigration both upstream and downstream of WVP dams. Our baseline dataset allows us to track changes in migration and survival as it relates to the constantly changing environmental variables among years.

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References

Banks , M.A., Britt, J., Sard, N., Hogansen, M., Schroeder, K., and Johnson, M.A. 2012 *in prep.* Genetic pedigree analysis of McKenzie River spring Chinook salmon: An evaluation of adult outplanting strategies. Summary Report to U.S. Army Corps of Engineers, Portland, Oregon. Oregon State University Department of Fisheries and Wildlife, Coastal Oregon Marine Experiment Station, Hatfield Marine Science Center, Newport

Beeman, J.W., Braatz, A.C., Evans, S.E., Haner, P.V., Hansel, H.C., and Smith, C.D. 2012 *in prep.* 2012. Passage probabilities of juvenile Chinook salmon through the powerhouse and regulating outlet at Cougar Dam, Oregon, 2011: U.S. Geological Survey Open-File Report 2012-xxxx, xxxp.

Britton, J. and K. Barko. 2006. Cougar Dam total dissolved gas investigation *as cited in* USACE (U.S. Army Corps of Engineers). Cougar Dam fish collection facility design documentation report #22. 2006. U.S. Army Corps of Engineers, Portland District, Portland, Oregon *and* NMFS (National Marine Fisheries Service). 2007. Endangered Species Act - Section 7 Consultation and Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Consultation on construction and operation of the Army Corps of Engineers fish trap at Cougar Dam. NMFS, Portland, Oregon.

Buchanan, D. V., M. G. Wade, and D. L. Higley. 1993. Restoration of the native winter steelhead runs on the South Santiam River above Foster Dam. Completion Report. Fish Research Project, OR. Oregon Department of Fish and Wildlife, Portland.

Bureau of Commercial Fisheries. 1960. Downstream migrant studies: South Fork McKenzie River 1957, 1959, 1960. U.S. Department of the Interior Report, Portland Oregon. pp. 1-24.

Cannon, B., R. Emig, T.A. Friesen, F. Monzyk, R.K. Schroeder, and C.A. Tinus. 2010. Work completed for compliance with the 2008 Willamette Project Biological Opinion, USACE funding: 2009. Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order: NWPPM-09-FH-05. Hatchery Research Monitoring and Evaluation, Oregon Department of Fish and Wildlife, Corvallis.

Cannon, B., R. Emig, T. A. Friesen, M. Johnson, P. Olmsted, R. K. Schroeder, C. S. Sharpe, C. A. Tinus, and L. Whitman. 2011. Work completed for compliance with the 2008 Willamette Project Biological Opinion, USACE funding: 2010. Annual report to the U.S. Army Corps of Engineers, Task Order NWPPM-10-FH-05. Hatchery Research Monitoring and Evaluation, Oregon Department of Fish and Wildlife, Corvallis, OR.

Friesen, T. A., M. A. Johnson, and P. M. Olmsted. 2012 *in prep*. Outmigration of hatchery spring Chinook salmon released above and below dams in the Middle Fork Willamette River. Annual report to the U.S. Army Corps of Engineers, Task Order W9127N-10-2-0005. Oregon Department of Fish and Wildlife, Corvallis, OR.

Keefer, M.L., G.A. Taylor, D.F. Garletts, C.K. Helms, G.A. Gauthier, T.M. Pierce, and C.C. Caudill. 2011. Reservoir entrapment and dam passage mortality of juvenile Chinook salmon in the Middle Fork Willamette River. Ecology of Freshwater Fish. pp. 1-13.

McGrath, K.E., E.M. Dawley, and D.R. Geist. 2006. Total dissolved gas effects on fishes of the lower Columbia River. Final report to U.S. Army Corps of Engineers, Portland, Oregon, Contract DE-AC05-76RL01830. Pacific Northwest National Laboratory, Richland, WA.

Mesa, M.G., L.K. Weiland, and A.G. Maule. 2000. Progression and severity of gas bubble trauma in juvenile salmonids. Transactions of the American Fisheries Society 129:174-185.

Monzyk, F. R., J. D. Romer, R. Emig, and T. A. Friesen. 2011. Pilot head-of-reservoir juvenile salmonid monitoring. Annual report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-0008: 1. Oregon Department of Fish and Wildlife, Corvallis, OR.

Monzyk, F.R., J.D. Romer, R. Emig, and T.A. Friesen. 2012. Life-History Characteristics of Juvenile Spring Chinook Salmon Rearing in Willamette Valley Reservoirs. Annual Report to U.S. Army Corps of Engineers, Portland, Oregon. Task Order W9127N-10-2-0008: 7. Oregon Department of Fish and Wildlife, Corvallis.

NMFS (National Marine Fisheries Service). 1999a. Endangered and threatened species: threatened status for two ESUs of steelhead in Washington and Oregon. Federal Register 64:14517-14528.

NMFS (National Marine Fisheries Service). 1999b. Endangered and threatened species: threatened status for three Chinook salmon evolutionarily significant units (ESUs) in Washington and Oregon, and endangered status of one Chinook salmon ESU in Washington. Federal Register 64:14307-14328.

NMFS (National Marine Fisheries Service). 2008. 2008-2023 Willamette River Basin Project Biological Opinion. NOAA's National Marine Fisheries Service, Northwest Region, Seattle, WA. F/NWR/2000/02117.

Tabor, R.A., K.L. Fresh, R.M. Piaskowski, and H.A. Gearns. 2011. Habitat use by juvenile Chinook salmon in the nearshore areas of Lake Washington: Effects of depth, lakeshore development, substrate, and vegetation. North American Journal of Fisheries Management 31:700-713.

Taylor, G. 2000. Monitoring of Downstream Fish Passage at Cougar Dam in the South Fork McKenzie River, Oregon 1998-00 Final Report, Oregon Department of Fish and Wildlife, Springfield OR. pp.1-9.

Thedinga, J. F., M. L. Murphy, S. W. Johnson, J. M. Lorenz, and K. V. Koski. 1994. Determination of salmonids smolt yield with rotary-screw traps in the Situk River, Alaska, to predict effects of glacial flooding. North American Journal of Fisheries Management 837-851.

Zymonas, N.D., J.V. Tranquilli, and M. Hogansen. 2012 *in prep*. Monitoring and evaluation of impacts to bull trout (Salvelinus confluentus) and spring Chinook salmon (*Oncorhynchus tshawytscha*) in the South Fork McKenzie River from construction of water temperature control facilities at Cougar Dam, Oregon. Final Report to U.S. Army Corps of Engineers, Portland, Oregon. Oregon Department of Fish and Wildlife, Corvallis.

Appendices

Appendix A. PIT tag information.

Table A1. Number of yearling and subyearling Chinook salmon tagged at each sampling location in 2011.

Location	Subyearling	Yearling	Total
SF McKenzie[a]	603	12	615
Cougar Reservoir[b]	485	62	547
Cougar Tailrace[c]	816	256	1,076
Breitenbush River[d]	109	2	111
North Santiam River[e]	171	13	184
Detroit Reservoir	54	4	58
Detroit Tailrace	66	0	66
Middle Fork Willamette	19	17	36
NF Middle Fork Willamette[f]	78	0	78
Lookout Point Reservoir[g]	65	7	72
South Santiam River		1	1
Foster Tailrace	2	0	2
Grand Total	2,468	374	2,842

[a]378 of the subyearlings were tagged while seining
[b]One age-2 fish that was tagged but not included in table
[c]Four age-2 fish tagged. Eight juveniles were captured by USGS in the reservoir, tagged and subsequently released in the tailrace
[d]All 109 subyearlings were tagged while seining
[e]Seven subyearlings and one yearling were tagged while seining
[f]All 78 subyearlings were tagged while seining
[g]Two age-2 fish tagged, not included in table

Table A2. Juvenile Chinook salmon tagged upstream of Willamette Valley Project in 2010-2011and subsequently detected at downstream recapture or interrogation sites.

Tagging Location	Recap/Interrogation Location	Detection Events 2010	Detection Events 2011
North Santiam River	Willamette Falls	3	1
	Columbia River Trawl	1	0
Breitenbush River	Willamette Falls	0	0
Detroit Reservoir	Willamette Falls	0	1
South Santiam River	Willamette Falls	4	0
South Fork McKenzie River	Cougar Reservoir	0	2
	Cougar Tailrace	0	3
	Leaburg	0	5
	Walterville	NA	0
	Willamette Falls	0	0
	Columbia River Trawl	0	0
Cougar Reservoir	Cougar Reservoir	2	5
	Cougar Tailrace	5	5
	Leaburg	21	7
	Walterville	NA	2
	Willamette Falls	3	1
	Columbia River Trawl	0	0
Middle Fork Willamette River	Willamette Falls	0	0
Lookout Point Reservoir	Willamette Falls	1	0

Appendix B. Basin-wide information.

Table B1. Number of adult female spring Chinook salmon outplanted upstream of Willamette Valley reservoirs 2009-2010 (Cannon et al. 2010, 2011).

Upstream of Reservoir	River	Year	♀ Outplants
Detroit	Breitenbush	2009	36
		2010	397
	North Santiam	2009	111
		2010	746
Foster	South Santiam	2009	172
		2010	232
Cougar	South Fork McKenzie	2009	629
		2010	320
Lookout Point	North Fork Middle Fork Willamette	2009	361
		2010	573

Appendix C. South Fork McKenzie River and Cougar Dam.

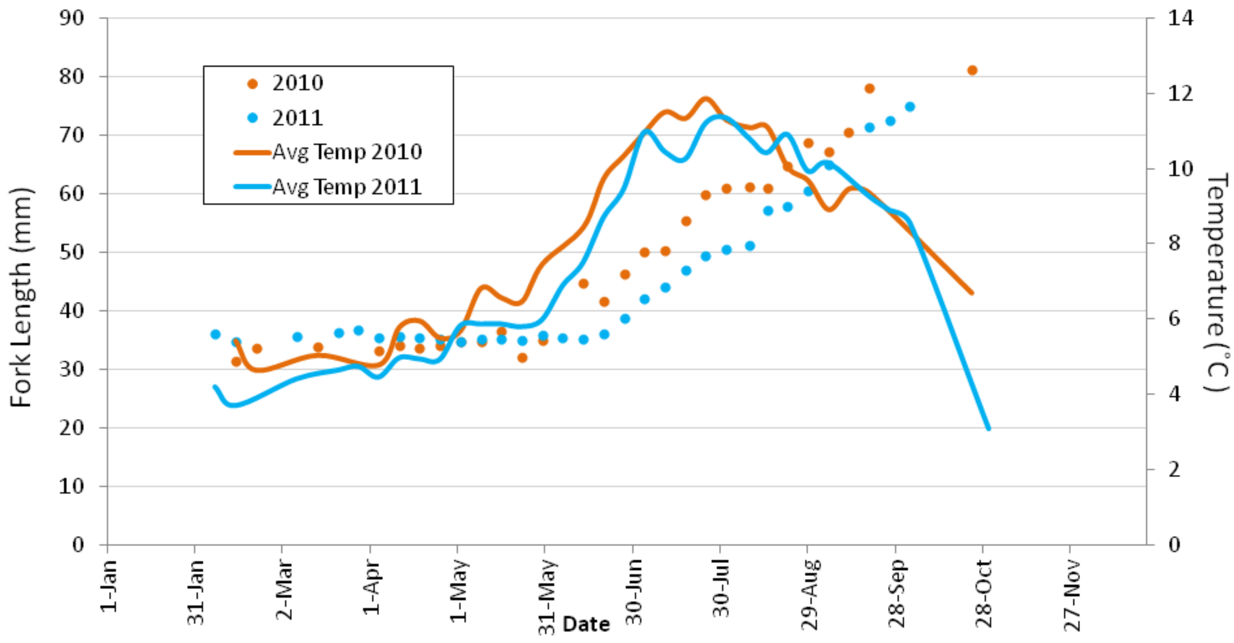

Figure C1. Comparison of temperature and average growth summarized by week for the South Fork McKenzie River, 2010-2011.

Table C1. Wilcoxon Rank Sum Test results comparing fork lengths of fish exiting Cougar Dam from the tailrace and RO during 2010 and 2011 (November-December). Data from November and December were combined for each year.

Comparison	Variable	n	Median Fork Length (mm)	25% (mm)	75% (mm)	T statistic	*P*-value
Tailrace to RO 2011	Tailrace	416	128	119	140	213812.5	<0.001
	RO	702	132	121	146		
Tailrace to RO 2010	Tailrace	2,716	115	108	125	1018859.0	0.861
	RO	614	116	107	126		
2011 to 2010	2010	3330	115	107	125	3431239.0	<0.001
	2011	1,118	130	120	144		

Table C2. Number of fish tagged (#tag) in the regulating outlet channel and tailrace below Cougar Dam and subsequently detected (#det) at downstream detection sites, 2011. Catch from the tailrace and regulating outlet were kept separate, and no tagging occurred in January.

Month	Regulating Outlet		Tailrace	
	#det / #tag	% Detected	#det / #tag	% Detected
February	0	--	0/2	0.0
March	0	--	1/4	25.0
April	0/62	0.0	6/56	10.7
May	5/85	5.9	1/4	25.0
June	2/24	8.3	1/2	50.0
July	0	--	9/19	47.4
August	0	--	4/33	12.1
September	0	--	4/17	23.5
October	0	--	26/86	30.2
November	72/375	19.2	81/261	31.0
December	9/26	34.6	9/12	75.0

Table C3. Number of fish tagged (#tag) in the regulating outlet channel and tailrace below Cougar Dam from November 19 - 30, 2011 and subsequently detected (#det) at downstream sites. Catch from the tailrace and regulating outlet were kept separate. Traps were not fished November 24-27.

November	Regulating Outlet		Tailrace	
	#det / #tag	% Detected	#det / #tag	% Detected
19-Nov	5/20	25.0	9/20	45.0
20-Nov	1/12	8.3	5/12	41.7
21-Nov	3/17	17.6	7/18	38.9
22-Nov	2/9	22.2	3/20	15.0
23-Nov	3/9	33.3	2/16	12.5
28-Nov	2/6	33.3	11/21	52.4
29-Nov	4/15	26.7	10/25	40.0

*Appendix D. Lookout Point Dam***.**

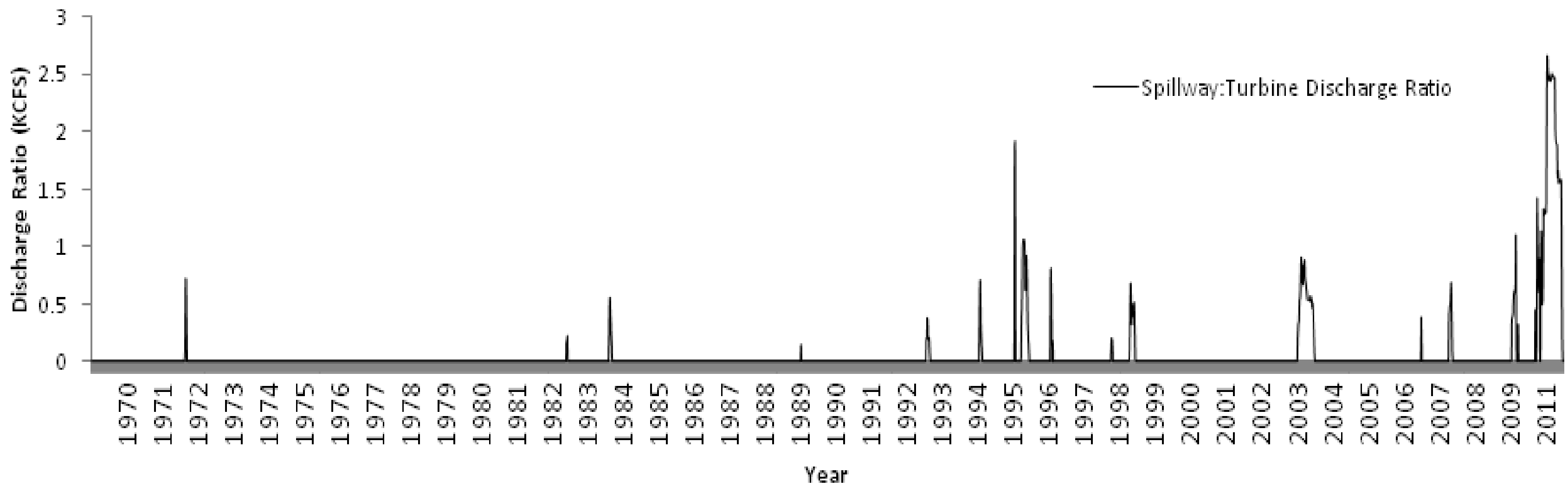

Figure D1. Lookout Point Dam spillway to tailrace discharge ratio, 1970-2011. Data compiled by Marc Johnson (ODFW).