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JUVENILE SALMONID OUTMIGRATION MONITORING AT WILLAMETTE VALLEY PROJECT RESERVOIRS

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Summary

To aid in the development of downstream passage options for juvenile salmonids at Upper Willamette reservoirs, we present results from screw trapping operations conducted upstream and downstream of USACE project dams in 2012. Traps upstream of dams were located on the North Santiam River 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 spring Chinook salmon *Oncorhynchus tshawytscha* and winter steelhead *O. mykiss* 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, and 4) estimate abundance of juvenile Chinook salmon entering reservoirs where trap efficiency (TE) criterion were met. 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 2012, screw traps were deployed upstream of reservoirs to capture newly emerged juvenile Chinook salmon. Trap deployment date varied by basin in accordance with emergence timing observed in previous sampling years. Traps remained fishing throughout the calendar year until removal in late November/December in anticipation of high stream discharge. 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. This suggests that prior to dam construction these fish likely would have continued dispersing downstream throughout the Willamette Basin similar to fry migration observed in unimpounded McKenzie River tributaries. Yearlings entering reservoirs were rare and generally collected in late winter and early spring.

Chinook salmon fry typically entered WVP 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 14. In the South Santiam River above Foster Reservoir, we captured 147 subyearling Chinook salmon and only one yearling. We suspect a high flow event in mid-January (13,000 ft^3/s) resulted in redd scouring and pushed any new emergents downstream into Foster Reservoir, similar to conditions and trapping results from 2011. Median migration date in the South Santiam was March 7, two months earlier than the South Fork McKenzie and North Santiam rivers. Nearly all (97%) of the subyearlings collected in the South Santiam trap were captured prior to May 1. 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. Peak reservoir entry into Lookout Point Reservoir was February-June with a median date of April 13.

The average fork length (FL) of fry entering most WVP reservoirs in the spring was 35 mm. Subyearlings captured in traps typically remained at this size until June, except migrants collected at the Middle Fork Willamette trap exhibited a relatively large variation in size as they entered Lookout Point Reservoir. We suspect this was partly due to the greater extent of rearing habitat between spawning areas and our trap in this sub-basin, allowing some juveniles to grow prior to capture. All juvenile Chinook salmon collected in upstream traps and *O. mykiss* in the South Santiam River > 65 mm FL were tagged with passive integrated transponders (PIT) to collect migration and growth information upon recapture.

Data collected from trapping below dams indicated that typically, very few fry continued migration through the reservoirs in the spring. We captured few fry in traps below Cougar and Lookout Point dams in 2012. However, the trap below Foster Dam captured Chinook salmon fry during a period similar to the trap located upstream of Foster Reservoir. This suggests that some fry (<50 mm fork length) were able to successfully migrate through Foster Reservoir. Most juvenile spring Chinook salmon exit WVP reservoirs as subyearlings in late fall/winter (October-February), in conjunction with reservoir drawdown and lowered pool elevation. In Lookout Point and Detroit reservoirs, several juvenile Chinook salmon were also captured between May and June during spill operations.

The South Santiam River is currently the only sub-basin above a WVP reservoir with winter steelhead production. Juvenile *O. mykiss* (presumably winter steelhead) were captured in the South Santiam screw trap throughout the year with the greatest catch occurring from July through November. Subyearling *O. mykiss* emerged and began moving downstream near the end of June and reached a maximum size of ~ 100 mm FL by the end of December. We captured 1,405 juvenile *O. mykiss* and PIT-tagged 321 upstream of Foster Reservoir in 2012. As in previous years, at least two year classes were present based on differences in fork length among cohorts.

Dam operators implemented several variations to the normal discharge operations at Cougar Dam in December 2012 to assist in research regarding juvenile Chinook salmon downstream passage. Corroborative evidence from a USGS radio tagging study (Beeman et al. 2013) and our screw traps demonstrated that a large majority of juveniles (>90%) exited Cougar Dam at night in December. Cougar Reservoir was also drawn down to a pool elevation ~10 m (30 ft) lower than the standard rule curve requires. The general pattern for fish leaving the reservoir appeared the same as observed in previous years, with the number of fish captured below the dam tapering off by the end of December, and we were unable to assess whether the 'deeper drawdown' caused an increase in the proportion of fish leaving the reservoir. However, it appears that the increased discharge and lower pool elevation may have advanced the timing of juveniles exiting the dam by several weeks.

Juvenile spring Chinook salmon collected in rotary screw traps below Cougar Dam were examined for externally visible injuries and corresponding injury codes were recorded. These were categorized into two categories, barotrauma or mechanical, and compared between the turbine and the regulating outlet (RO) passage routes. Fish with no visible external injuries comprised 58.7% and 14.9% of the catch exiting the turbines and RO, respectively. Among injured fish exiting the turbines, 5.6% had more than two injury codes compared to 18.0% for fish exiting the RO. Fish captured in the tailrace had a higher instance of injury associated with mechanical damage while barotrauma was more prevalent in the regulating outlet. Individual fish with injuries related to both mechanical and barotrauma were more frequently observed in the RO trap than in the tailrace.

Population estimates were calculated for the South Fork McKenzie River upstream of Cougar Reservoir. Migrant estimates were based on screw trap recapture information. For all other upstream traps, the trap efficiency was low or too few juveniles were captured to accurately calculate point estimates for the number of fish migrating past our traps. In the South Fork McKenzie we captured 6,482 Chinook salmon subyearlings, and estimated a total of 228,241 (95% CI ± 34,715) subyearlings that migrated past our trap and into Cougar Reservoir. The majority (88%) of subyearlings in 2012 moved into Cougar Reservoir as fry from April through June. Trap efficiency ranged from 1.8 to 18.9% with a yearly weighted TE of 2.9 %, exactly the same as the previous year.

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 includes 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 in the tailraces of Detroit, Foster, and Cougar dams. We also summarize data collected from traps below Lookout Point Dam that were operated by USACE personnel. Research objectives were to provide information on the migration timing and size of naturally produced juvenile salmonids entering and exiting select WVP reservoirs, and estimate the abundance of migrants at traps where possible. Juvenile Chinook salmon from all sub-basins and winter steelhead from the South Santiam River collected upstream of the reservoirs were progeny from adults that were trapped and hauled upstream of WVP dams. Fish collected in the Middle Fork Willamette trap included hatchery fish released in Hills Creek Reservoir. Fish collected below dams included naturally-produced progeny and hatchery fish released into some reservoirs (Detroit and Lookout Point reservoirs).

This report fulfills a requirement under Cooperative Agreement Number W9127N-10-2-0008, for outmigration monitoring from April 2012–March 2013. Data in this report includes summary and analysis of field activities implemented by ODFW on behalf of the USACE through December 31, 2012 to address requirements of RPA measures prescribed in the Willamette Project BiOp (NMFS 2008). 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.

Methods

Rotary Screw Traps

Above Project Traps- Traps deployed upstream of WVP reservoirs in 2012 were located on the North Santiam River 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, and trapping sites remained consistent with 2011 sampling locations (Romer et al. 2012; Table 1) with the exception of the Breitenbush River trap upstream of Detroit Reservoir. The Breitenbush trap was removed because no adult fish were outplanted here in 2011 (Sharpe et al. 2013). Deployment date for each trap varied by basin in accordance with expected emergence timing based on observations in previous sampling years (Monzyk et al. 2011; Romer et al. 2012). Traps remained fishing throughout the calendar year until removal in late November/December in anticipation of high stream discharge. The exception was the South Santiam trap which we kept in place throughout the calendar year. 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 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.

Below Project Traps- In addition, we continued trapping efforts in 2012 below Detroit Dam (1.5-m trap 579 m downstream of Detroit Dam), Foster Dam (2.4-m trap in the turbine tailrace) and Cougar Dam (two 2.4-m traps in the turbine tailrace, one 1.5-m trap in the regulating outlet channel). We also received and summarized migrant data from the 2.4-m trap operated by the USACE below Lookout Point Dam (Figure 1).

Below Detroit Dam we exchanged the 2.4-m trap with a 1.5-m trap to avoid further damage incurred the previous season due to large fluctuations of water level at this site. The smaller trap was located downstream of the dam near the lower end of the boat restricted zone (BRZ), which allowed us to capture fish exiting through all possible dam passage routes. However, repairs on Big Cliff Dam spillway gates are projected to be completed in fall 2013, allowing Big Cliff Reservoir to reach full capacity. This will increase fluctuation in water levels up to 8 m daily resulting in inundation of our current trapping site. As a result, we placed a 2.4-m trap near the tailrace of Detroit Dam in March 2013 to increase trapping efficiency and avoid hazardous conditions. We will continue operation of the 1.5-m trap until repairs on Big Cliff Dam are completed to compare catch information between the two traps. Although we will lose the ability to capture fish from both the spillway and the turbine outflow, we are hopeful that the trapping site in the tailrace will provide increased stability for trap operation and more consistent data collection.

At Cougar Dam, 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). The RO and tailrace empty into two separate channels which merge approximately 100 m downstream of the base of the dam. 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, one 1.5-m diameter trap in the regulating outlet). Initially, two traps were in the RO channel, but on March 10, 2012 one of the traps in the RO channel below Cougar Dam was removed as a safety precaution.

Below Foster Dam, the 2.4-m diameter trap was in the tailrace of the turbine discharge and did not capture fish exiting the reservoir via the spillways. 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 Willamette Valley Project reservoirs 2012. 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	Installation date	rkm	UTM (10T)
	Upstream of reservoirs		
Breitenbush	NA[a]	286	0568785 4955753
North Santiam	March 9	292	0575240 4949260
South Santiam	January 4	271	0539897 4915479
South Fork McKenzie	February 28	395	0562654 4877522
Middle Fork Willamette	February 15	358	0537699 4846035
	Below dams		
Detroit	January 9	271	0558956 4952722
Foster	January 3	253	0526128 4917989
Cougar	January 3	385	0560486 4886873
Lookout Point	January 5	333	0519724 4862480

[a] Trap not deployed in 2012; no adult fish were outplanted in the Breitenbush River in 2011.

Juvenile Salmonid Outmigration Timing and Size

Traps upstream of reservoirs were operated continuously throughout the year unless flows (high or low) were prohibitive (Figure 2), and traps below dams were dependent upon flow from dam discharge (Figure 3). All traps were generally 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 (TE) or days when the trap was not operated unless otherwise stated. The South Santiam trap (upstream of Foster Dam) was located downstream of adult winter steelhead outplanting locations which facilitated data collection for juvenile steelhead migration in addition to spring Chinook salmon.

Fish captured and removed from traps were anesthetized with MS-222 and enumerated by species and age class (subyearling and yearling based on size differences among cohorts in length frequency graphs). 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 and winter steelhead juveniles (Appendix A; Table A1; A2; A3) >65 mm FL were tagged with a passive integrated transponder (PIT) tag to collect recapture and detection information (Appendix A; Table A4) regarding growth and migration behavior. Growth information can be found in Monzyk et al. (2013).

We designated age based on length-frequency analysis. Yearling and subyearling Chinook salmon generally maintained a clear size difference throughout the year. For each trap, we graphed individual fish size by date and assigned age. Juveniles that hatched in spring 2012 (brood year 2011) were classified as subyearlings and yearlings were fish that hatched the previous year (brood year 2010) and remained in the reservoir after 01 January, 2012. We report outmigration timing during the calendar year (Jan-Dec). Therefore, yearlings and subyearlings comprise different cohorts.

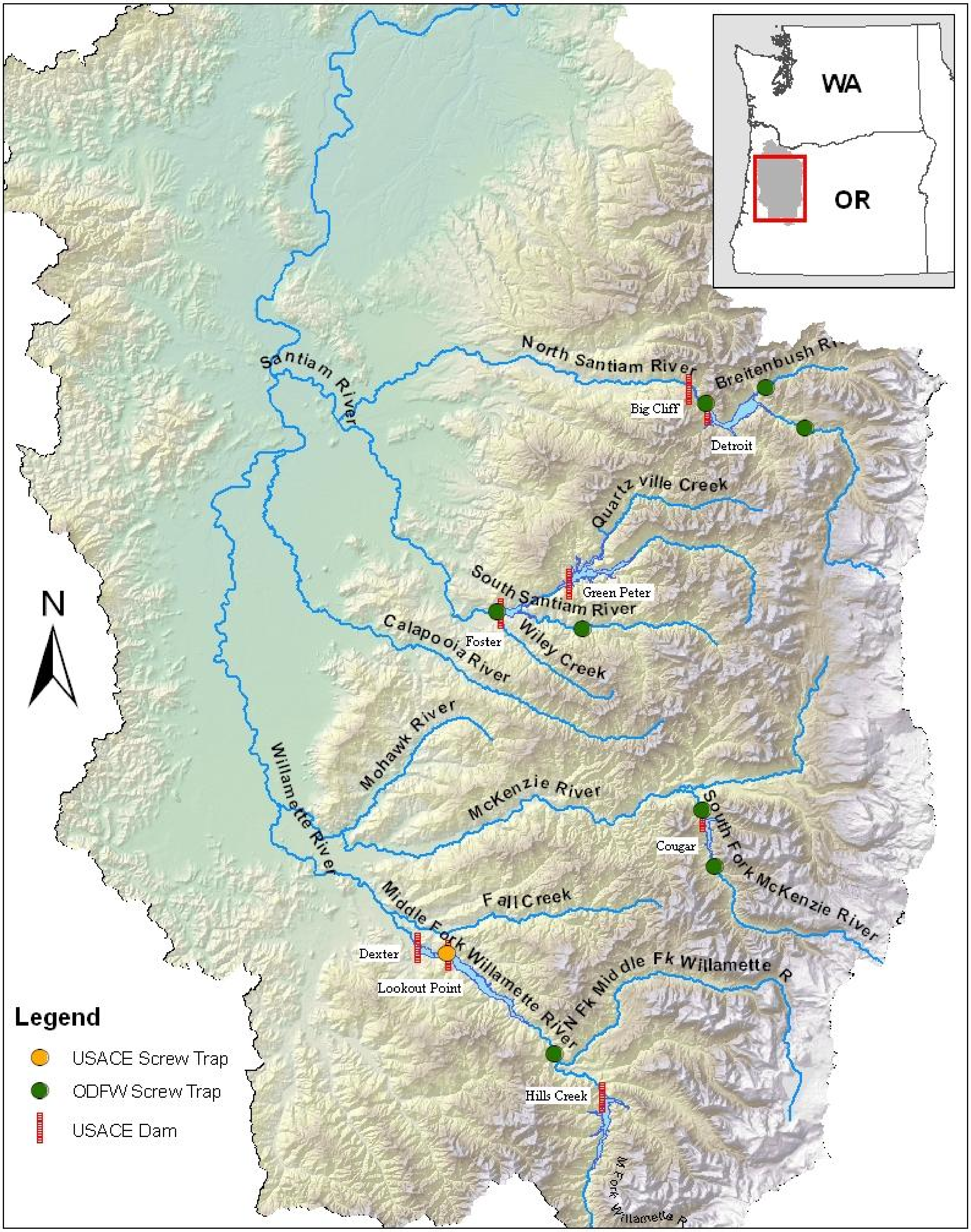

Figure 1. Locations of rotary screw traps operated by ODFW and USACE above and below Willamette Valley Project dams. The Breitenbush River trap was not operated in 2012.

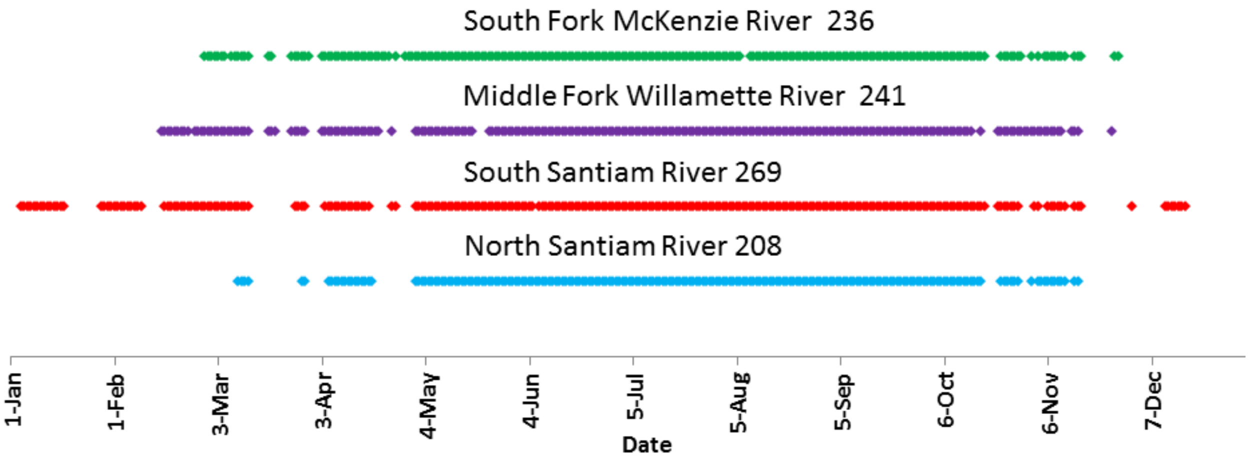

Figure 2. Screw trap operation summary for traps upstream of Willamette Valley reservoirs, 2012. Each colored dot represents one day of operation; numbers are the number of days the trap was operated during the calendar year.

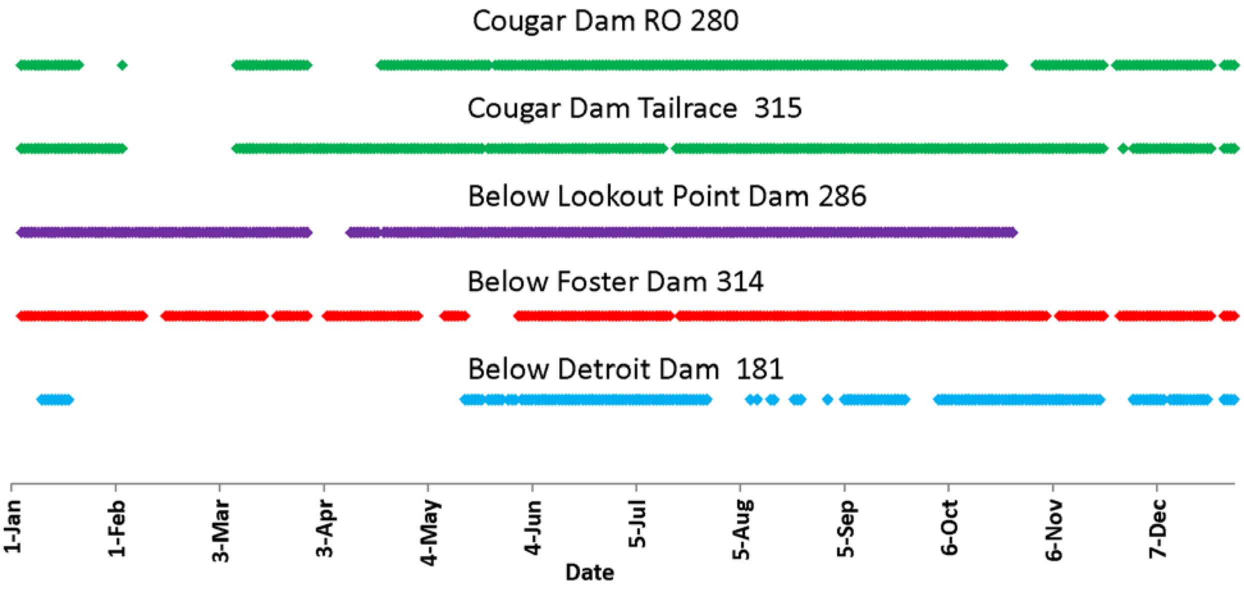

Figure 3. Screw trap operation summary for traps below dams in the upper Willamette Basin, 2012. Each colored dot represents one day of operation; numbers are the number of days the trap was operated during the calendar year.

Special Operations below Cougar Dam

In November and December 2012, dam operators implemented special discharge operations at Cougar Dam to assist several studies of juvenile Chinook salmon downstream passage. During this period our traps were checked daily.

Day vs. Night Dam Passage – From November 7-15, special operations were implemented where only the RO was running at night (turbines off). From December 6-16, both the RO and turbines were running continuously (day and night). We compared the proportion of fish captured exiting each route between the two periods to determine whether fish were passing through the dam during the day or at night.

Deeper Drawdown - In mid-December, Cougar Reservoir was drawn down to a minimum pool elevation of 1,500 ft to help increase the proportion of juvenile Chinook salmon leaving the reservoir. This level was 30 ft (~10 m) lower than the standard rule curve requires. Turbines were not operated after the reservoir pool level descended below 1,525 ft, and all subsequent flow discharged through the regulating outlet. Lowering the reservoir pool level decreased the distance that fish had to dive to reach an opening for exiting the dam (RO 1,485 ft, turbines 1,426 ft above sea level). Increased surface flow toward the dam created by increased discharge and lower pool elevation are believed to be more conducive to juvenile fish passage. We used data provided by the USACE to illustrate route specific daily discharge, pool elevation, and catch numbers for December (Figure 24).

Injury Summary below Cougar Dam

We assessed injuries for juvenile spring Chinook salmon only below Cougar Dam; this was the only facility where we were able to distinguish the exit route used and collect enough fish to provide a meaningful analysis. All fish entrained for dam passage at Cougar Dam must enter the temperature control tower prior to dam passage and have two possible routes by which they can exit the dam. The “tailrace” route includes passing through turbines. The regulating outlet (RO) has no turbines but fish must pass through a knife gate at the top of a steep concrete spillway which empties into a large plunge pool at the bottom. We examined juvenile spring Chinook salmon collected in rotary screw traps below dams (dead and live) for external injuries, parasites and disease (Table 2). Injury codes were developed for commonly occurring anomalies observed by field crews and based on protocols used in the Columbia River by the Pacific States Marine Fisheries Commission (Martinson et al. 2009). We used the occurrence of external injuries observed on both dead and live fish captured in screw traps below Cougar Dam to describe injuries associated with dam passage, and compare injury type, abundance, and proportion observed between routes. We chose the presence of external injury as a response variable rather than immediate survival to the traps, as we suspect injuries may be more indicative of potential delayed mortality associated with the passage routes.

Percent Occurrence for Each Injury Code- Percent injury is defined as the number of times a single injury occurred, divided by the number of fish exiting the specified route with at least one injury code. It was possible for one fish to exhibit multiple injuries. Disease, parasites, fin damage, and predation codes (COP, BKD, FUN, FID, PRD) were recorded but not included in calculations, as these abnormalities were not considered to be associated with dam passage. Live fish with no external injuries (NXI) and mortalities with no external injuries (MUNK) were counted and the percentage was calculated from the total number of fish captured but were excluded from the percent of injury calculations. We tested for significant differences in the proportion of injured fish between routes using a z-test ($\alpha = 0.05$).

Barotrauma vs. Mechanical Damage- Injury codes were partitioned into two categories associated with the suspected cause of the injury (mechanical or barotrauma; Table 2). Both categories included injuries considered to be directly related to dam passage, and only fish exhibiting injuries associated with these categories were used for comparison. It was possible for a single fish to have injuries associated with both categories. If a fish exhibited no visible injury, died but did not have observable external injuries (MUNK), or had descaling less than 20% (DS<20), it was not considered as an injury associated with dam passage and was excluded from the summarized data.

Table 2. List of codes used to describe and summarize fish injuries observed below Willamette Valley project dams.

Description of Injury/Condition	Injury Code	Injury Category
Live fish with no external injuries	NXI	N/A
Mortality with no external injuries	MUNK	N/A
Descaling < 20%	DS<2	N/A
Bloated	BLO	Barotrauma
Bloody Eye (hemorrhage)	EYB	Barotrauma
Bleeding from Vent	BVT	Barotrauma
Fin Blood Vessels Broken	FVB	Barotrauma
Gas Bubble Disease (fin ray/eye inclusions)	GBD	Barotrauma
Pop Eye (eye popping out of head)	POP	Baro/Mech
Head Injury	HIN	Mechanical
Opercle Damage	OPD	Mechanical
Body Injury (tears, scrapes, mechanical damage)	TEA	Mechanical
Bruising (any part of body)	BRU	Mechanical
Hole Behind Pectoral Fin	HBP	Mechanical
Descaling > 20%	DS>2	Mechanical
Head Only	HO	Mechanical
Body Only	BO	Mechanical
Head Barely Connected	HBO	Mechanical
Fin Damage	FID	N/A
Predation marks (vert. claw or teeth marks)	PRD	N/A
Copepods (on gills or fins)	COP	N/A
BKD (distended abdomen)	BKD	N/A
Fungus	FUN	N/A

Abundance Estimates of Outmigrating Chinook Salmon

We calculated capture efficiency 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 or a small clip from the caudal fin) 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 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 where 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 (< 5 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; 1,000 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

Juvenile Salmonid Migration Timing and Size

Chinook salmon 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 among sub-basins. Few subyearlings were collected from mid-June through the end of December at any of the trap sites, providing evidence 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 was below Lookout Point Dam where the greatest catch occurred May through June and was associated with surface spill events, similar to 2011. Below Detroit Dam we captured more Chinook salmon in May - June than in 2011, but total catch was much lower than in 2011.

North Santiam River- We operated the North Santiam River trap upstream of Detroit Reservoir from March 8 through November 30, 2012. The run timing and size of subyearlings captured 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 4) with a median migration date of May 14 (Appendix B; Table B2). Most subyearlings entered Detroit Reservoir from April through June as fry averaging 35 mm FL (Figure 5). The size range for subyearlings caught throughout the sampling period was 33-135 mm FL.

The North Santiam trap fished for 208 d in 2012, and captured 146 Chinook salmon subyearlings, 16 yearlings, and eight suspected hatchery fish (Figure 5). We PIT-tagged 25 unmarked juvenile spring Chinook. Suspected hatchery fish were identified by intermediate size and worn caudal and dorsal fins. Several hatchery fish were confirmed to have escaped during a marking (AD clip) session at Marion Forks Hatchery just before suspected hatchery fish were collected in our screw trap. We captured 4,255 subyearlings in the North Santiam screw trap in 2011. The disparity in capture numbers between years is directly related to the number of females outplanted in the preceding years (746 females in 2010, 63 in 2011; Appendix B; Table B1).

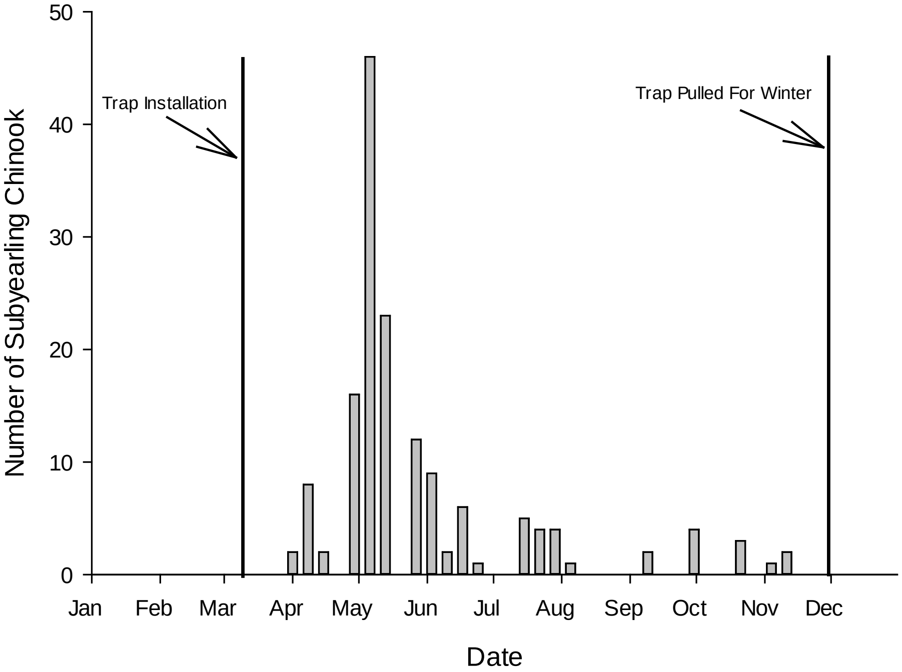

Figure 4. Weekly abundance of subyearling spring Chinook salmon captured in the North Santiam trap above Detroit Reservoir, 2012.

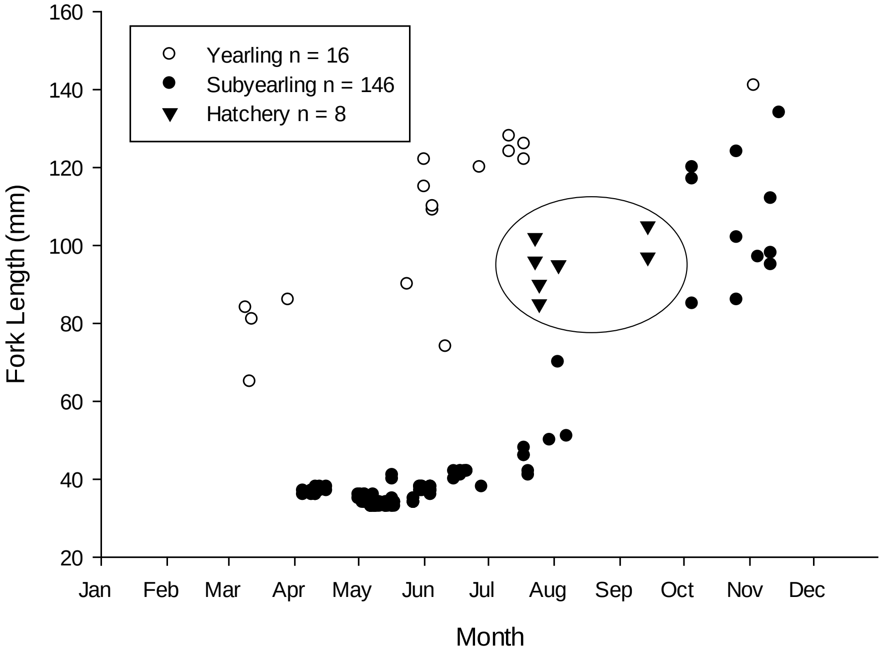

Figure 5. Fork lengths of juvenile Chinook salmon captured in the North Santiam trap upstream of Detroit Reservoir on a temporal scale, 2012. Suspected hatchery fish are circled.

Breitenbush River- We did not operate the Breitenbush River trap during the 2012 field season, as there were no adult Chinook salmon outplanted in the Breitenbush in the fall of 2011. Very few adult female spring Chinook (23) were outplanted again in 2012 (Appendix B; Table B1), and only two redds were observed during spawning ground surveys conducted here in 2012. Therefore we do not anticipate running the trap during the 2013 field season. However, the screw trapping infrastructure was maintained in anticipation of increased adult Chinook salmon outplanting in 2013 with the completion of the new Minto adult collection facility.

Below Detroit Dam- We replaced our 2.4-m diameter rotary screw trap downstream of Detroit Dam with a smaller 1.5-m trap that did not fish as deep to avoid contact with bedrock; a problem at this location in the past. We fished the trap from January 9 through December 30, 2012. 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. At flows exceeding 6,000 cfs we were unable to access the trap due to safety concerns. There were instances when Big Cliff Reservoir backed up to the trap site, resulting in inadequate flow to operate the trap. In addition, the reservoir level fluctuated approximately 2 m between trap checks, leaving the trap partially perched on bedrock or otherwise compromising fishing ability. The trap was pulled from January 21 – May 14 for safety modifications, and coupled with the dynamic reservoir elevations of Big Cliff Reservoir and large changes in flow at the trapping site, this trap only operated 51% (181/355) of the days that were available for fishing, resulting in limited data (Figure 6).

We captured 31 unmarked Chinook salmon, 74 hatchery Chinook salmon, and 1,084 kokanee *O. nerka* below Detroit Dam in 2012. The overall percent mortality for each of these species recovered from the trap was 29%, 20%, and 97% respectively. The hatchery Chinook salmon originated from the release of approximately 62,500 adipose-clipped juveniles for a paired release study (median FL 90 mm, 12,500 PIT tagged) into Detroit Reservoir on August 10, 2012 (Friesen et al. 2013 *in prep.*). Trap catch also included incidental species such as mysis shrimp *Mysis relicta,* pumpkinseed *Lepomis gibbosus*, and rainbow trout *O. mykiss* (Table 3).

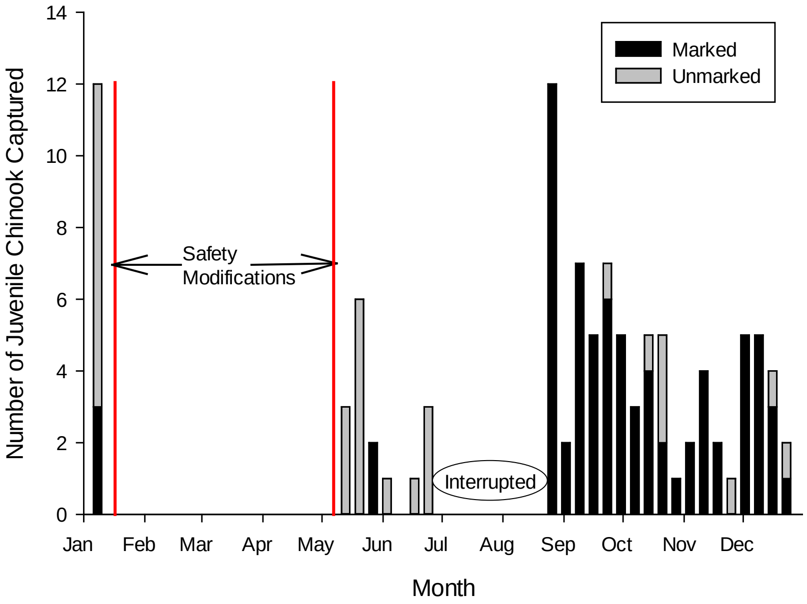

Figure 6. Weekly abundance of marked and unmarked Chinook salmon (subyearling and yearlings) captured in the rotary screw trap below Detroit Dam, 2012. Interrupted indicates a period when the cone was damaged or debris kept the trap from operating.

Since 2007, summer spill operations have been used to control downstream temperatures. In 2012, spring spill operations started on April 2 and we captured yearling Chinook as soon as the trap was re-deployed following safety modifications in mid-May (Figure 6). We observed increased numbers of juvenile Chinook salmon passing through Detroit Dam in August - September of 2011 and 2012. Whether juvenile Chinook salmon passage through Detroit Dam during the summer has always occurred through the turbine discharge or was associated with the spill is unclear. We included dam operation and flow discharge information (Figure 7) to provide context for the fish trapping data.

Table 3. Number of fish captured in the screw trap below Detroit Dam by species and month, 2012. The trap was not operated February – April while safety modifications were made. Mysis shrimp counts are estimates. Mk = fin-marked; Unmk = unmarked.

Month	Chinook Mk	Chinook Unmk	Rainbow Trout Mk	Kokanee	Mountain Whitefish	Dace	Pumpkinseed & Bluegill	Mysis Shrimp
JAN	3	9	3	6	0	0	0	0
FEB	Safety Modifications							
MAR								
APR								
MAY	2	9	2	0	0	2	8	0
JUN	0	5	6	5	0	10	10	0
JUL	0	0	4	0	1	10	19	0
AUG	12	0	0	0	0	0	0	0
SEPT	20	1	0	0	1	0	943	0
OCT	15	4	0	159	0	0	767	1,500
NOV	8	1	8	246	0	0	100	300
DEC	14	2	15	668	0	0	0	100
TOTAL	74	31	38	1,084	2	22	1,847	1,900

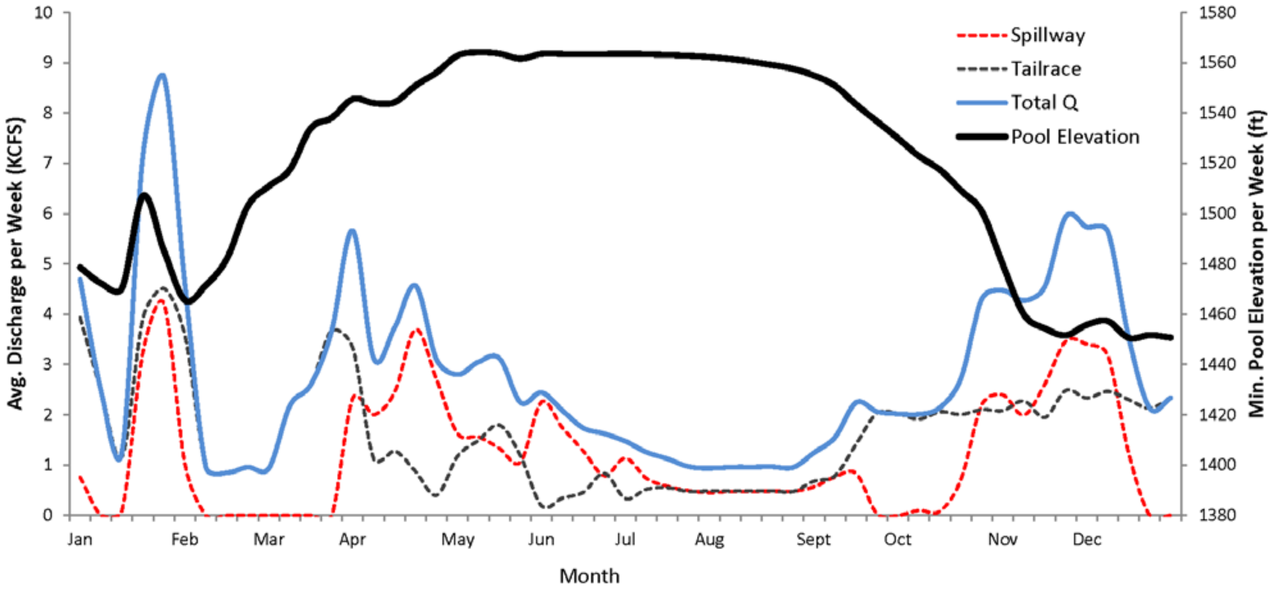

Figure 7. Detroit Dam discharge (Q) and reservoir pool elevation, 2012. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week.

South Santiam River Spring Chinook Salmon- We operated the South Santiam trap upstream of Foster Reservoir from January 4 through December 17, 2012. The trap fished for 269 days. Catch rates for Chinook salmon remained low as in 2011. We captured 147 Chinook salmon subyearlings, one yearling (137 mm FL), and PIT-tagged 12 fish. Peak fry movement was in February and March (Figure 8), with a median migration date of March 7. Most (97%) of the Chinook salmon subyearlings were captured prior to May 1.

In 2012, the South Santiam River experienced a flow event peaking at 13,000 ft^3/s on January 19, similar to the flow experienced on January 16, 2011 (11,800 ft^3/s; flow data from USGS gauging station 14158000 near Cascadia) that we believed may have contributed to a nearly complete year-class failure for the 2010 brood year. The small catches we observed in 2011 and 2012 suggest that flows >10,000 ft^3/s in mid-January are not conducive to in-stream rearing for juvenile Chinook salmon. High flows that occur early in the year likely push fry downstream into Foster Reservoir or may displace redds, causing direct mortality to eggs and alevins residing in the interstitial spaces. The South Santiam River has a deeply incised channel, and a majority of the accessible spawning substrate is perched on bedrock (Romer et al. 2012). Prior to the addition of Green Peter Dam (1967) on the Middle Santiam River and Foster Dam (1968) on the South Santiam River, the major spring Chinook salmon spawning areas in the South Santiam system were the Middle Santiam River, Quartzville Creek, and a five mile reach upstream of Cascadia on the South Santiam River. Historically, 85% of the spring Chinook production in the South Santiam system occurred above Foster Dam (Mattson 1948 *as cited in* Wevers et al. 1992).

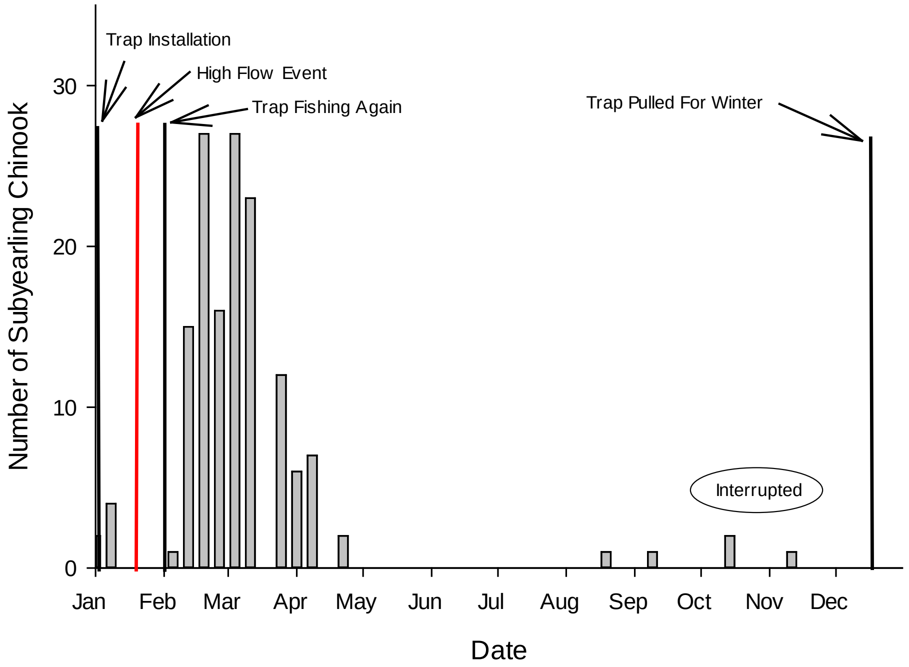

Figure 8. Weekly abundance of subyearling spring Chinook salmon captured in the South Santiam trap above Foster Reservoir, 2012. Interrupted indicates periods when the trap was running intermittently due to low flows or debris stopping rotation of the trap.

South Santiam River Winter Steelhead- Juvenile steelhead exist in sympatry with resident rainbow trout in the South Santiam River and cannot be distinguished from one another in the field; we refer to both life-history types as *O. mykiss.* We captured 1,405 juvenile *O. mykiss* and PIT tagged 321 in the South Santiam trap in 2012. Based on fork lengths, there were at least two distinct year classes present (Figure 9). The first subyearling from the 2012 brood year (BY) was captured on June 22 (30 mm FL). These subyearlings, presumably progeny from adult steelhead outplanted above Foster Reservoir, were captured about two weeks earlier than in 2011 (July 8, 26 mm FL). Catch peaked in mid-August and continued through November (Figure 10). This subyearling cohort reached a maximum fork length of approximately 100 mm and comprised 89% of the total *O. mykiss* catch for the year. Another year-class (presumably age 1) was also present, with a size range of approximately 100-180 mm FL (Figure 9).

We PIT tagged 323 *O. mykiss* >65 mm FL of unknown life history type at the South Santiam screw trap in 2012. None of these fish were recaptured in our trap below Foster Dam or detected downstream at Willamette Falls. However, two juvenile *O. mykiss* captured and tagged in November 2011 as age-1 juveniles (128 and 132 mm FL) at our South Santiam trap were detected by the NOAA Fisheries trawl in the upper Columbia River estuary during April 2012 as age-2 ocean-bound smolts.

Smolting age is defined as the number of winters spent in fresh water prior to outmigration to the ocean. Typical life history patterns observed for naturally-produced winter steelhead are dominated by age-2 smolts in the Columbia and Snake rivers as well as coastal Oregon streams where there are sufficient data available (Busby et al. 1996). Preliminary data suggest that a majority of the winter steelhead in the South Santiam River move downstream past our trap as subyearlings and continue to rear farther downstream. These fish then subsequently migrate to the ocean as age-2 smolts (based on two detections). Future data collected from our continued trapping and tagging efforts upstream of Foster Reservoir, below Foster Dam, and in conjunction with the passive interrogation antenna at Willamette Falls should provide greater insight on the migration behavior of winter steelhead from this sub-basin. It will also allow collection of information regarding the growth of resident *O. mykiss* that we might recapture in our screw trap upstream of the reservoir as they undergo in-stream migration associated with resident spawning behavior.

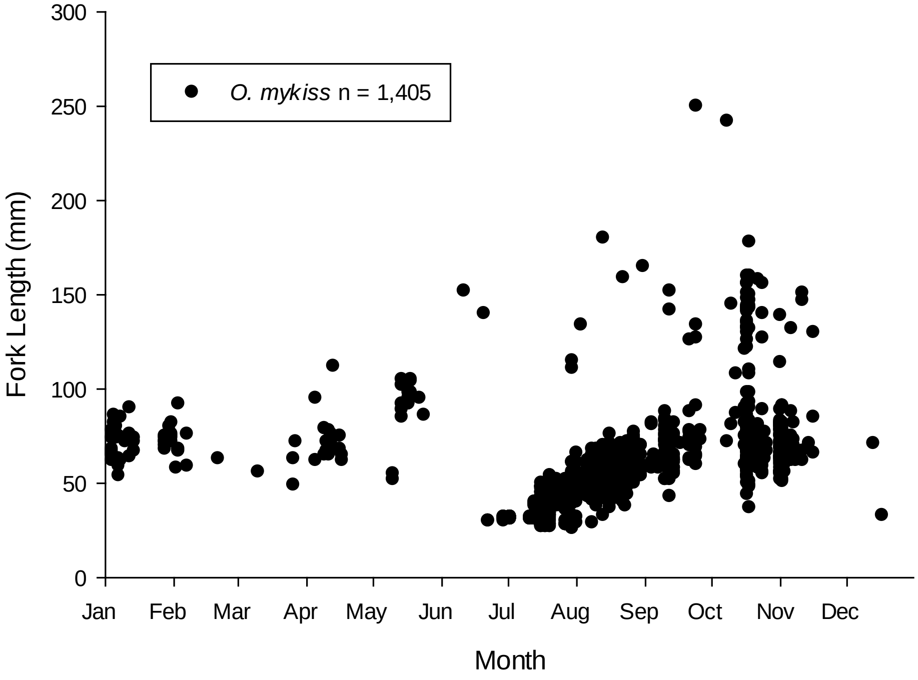

Figure 9. Fork lengths of *O. mykiss* caught in the South Santiam trap above Foster Reservoir, 2012.

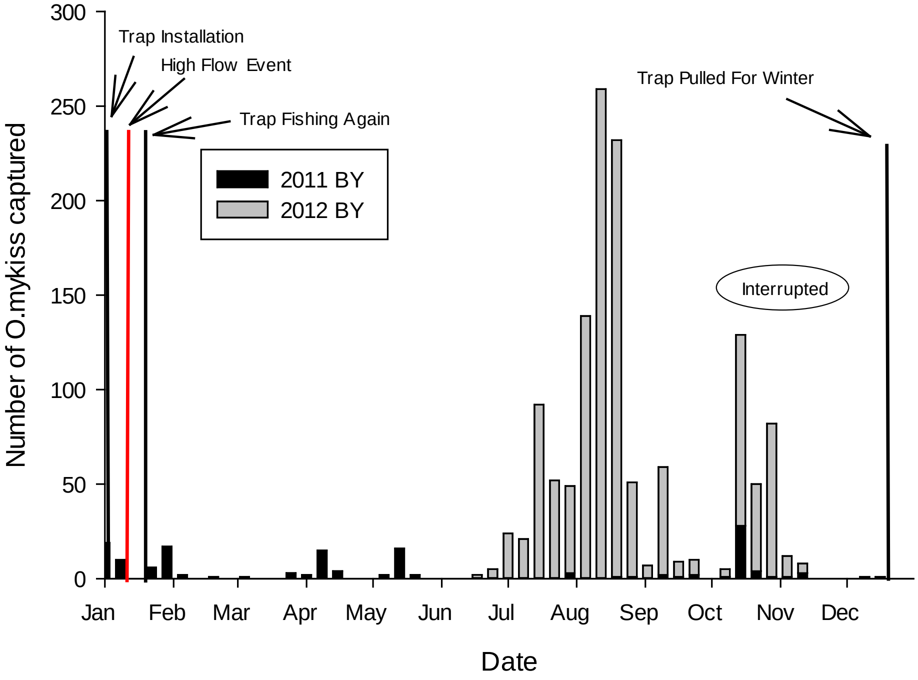

Figure 10. Weekly abundance of juvenile *O. mykiss* captured in the South Santiam trap above Foster Reservoir, 2012. Catch includes 2011 and 2012 brood years (BY). Interrupted indicates a period when the trap was not operating consistently because of low flow or debris.

Below Foster Dam - The trap below Foster Dam operated from January 3 – December 30, 2012. The trap ran 87% of the days that were available for fishing (314/361). This trap was pulled from February 9-15 for safety modifications, and again May 16 – May 30 to accommodate a balloon tag study conducted by Normandeau Associates, Inc.

We captured 134 unmarked subyearling Chinook salmon throughout the year, with timing and size of the first subyearlings in January similar to timing of emergents captured in the South Santiam trap upstream of Foster Reservoir. Most of the subyearlings (87%) were captured from January-April with a mean size of 37 mm FL (range: 25-42 mm FL). The migration timing and size of subyearling Chinook salmon collected here suggests that some subyearling Chinook salmon moved through Foster Reservoir into downstream rearing areas when the reservoir was at low pool elevation. Our screw trap is positioned just downstream of the turbine outflow and is unable to sample fish exiting via the spillway. However, given the shallow turbine penstocks, our screw trap catch in the tailrace likely reflects the migration timing and abundance of subyearling salmonids.

We also captured 87 subyearling *O. mykiss* from August 3 through December 31, 2012, with capture numbers peaking in November (Figure 11). This timing was delayed in comparison to the capture of new emergents upstream of the reservoir which began arriving in the third week of June. In contrast to Chinook salmon, most subyearling *O. mykiss* enter the reservoir at full pool elevation with a greater distance to travel and less flow through the reservoir for guidance due to decreased discharge from the South Santiam River and decreased discharge at Foster Dam.

The Foster Dam fish weir, deployed to facilitate juvenile *O. mykiss* passage through the reservoir, is currently operated annually from April 15 to May 15. The weir operation dates were originally based on the outmigration timing of progeny from adult hatchery winter steelhead that were outplanted upstream of Green Peter Reservoir (Wagner and Ingram 1973). Similarly, in the nearby Clackamas River (and several associated sub-basins), juvenile winter steelhead downstream movement peaks in April and May (Strobel 2006; Wyatt 2009). However, our data shows that the duration of weir operation may not coincide with downstream migration timing for juvenile *O.mykiss* from the South Santiam River (Figure 10 and 12). Migration data collected upstream and downstream of Foster Reservoir suggest that weir operations or surface spill during the fall and winter months may be more effective for moving subyearling *O. mykiss* through the reservoir. Buchanan et al. (1984) noted that few hatchery or wild smolts used surface spill until late April during 1981-1983. They also suggested that passage through subsurface routes at high discharge (> 3,400 cfs) and low reservoir level increased smolt passage and contributed to higher smolt to adult survival rates. These are similar to conditions we observed in 2012 (Figure 13). It is possible that steelhead smolts (≥ 120 mm) may be passing over the spillway where we are not able to capture them in our screw trap, or smolts exiting turbines are large enough to avoid the trap.

Trap catch included incidental species such as yellow perch *Perca flavescens*, kokanee, cutthroat trout *O. clarkii*, yellow and brown bullhead *Ameiurus* spp., bluegill and pumpkinseed *Lepomis* spp., largescale sucker *Catostomus macrocheilus*, brook lamprey *Lampetra richardsoni*, northern pikeminnow *Ptychocheilus oregonensis*, smallmouth bass *Micropterus dolomieu,* and white crappie *Pomoxis annularis* (Table 4). Bluegill and yellow perch were the most abundant species in our trap catch with large numbers captured in November and December, coinciding with lower reservoir levels and increasing spillway discharge (Figure 13).

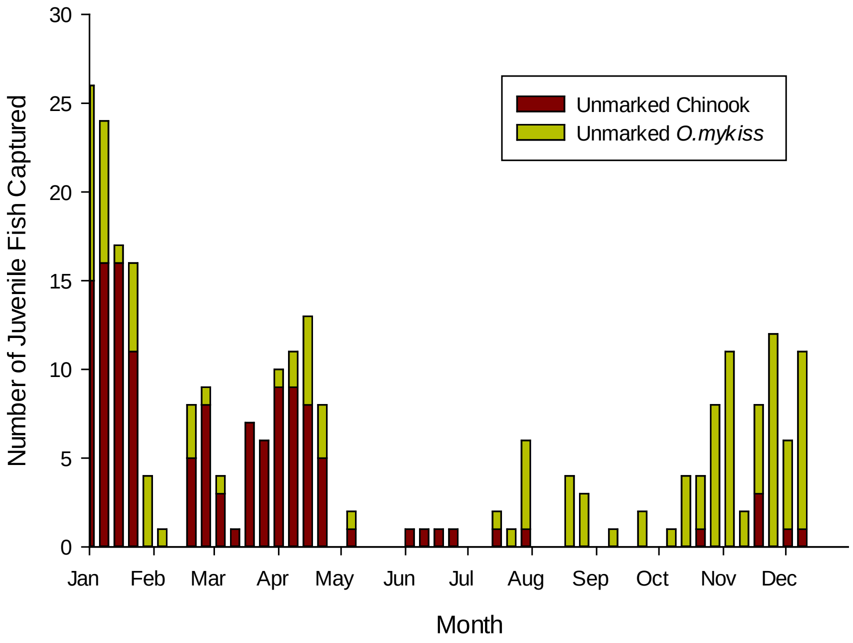

Figure 11. Weekly abundance of unmarked Chinook salmon and *O. mykiss* captured below Foster Dam, 2012.

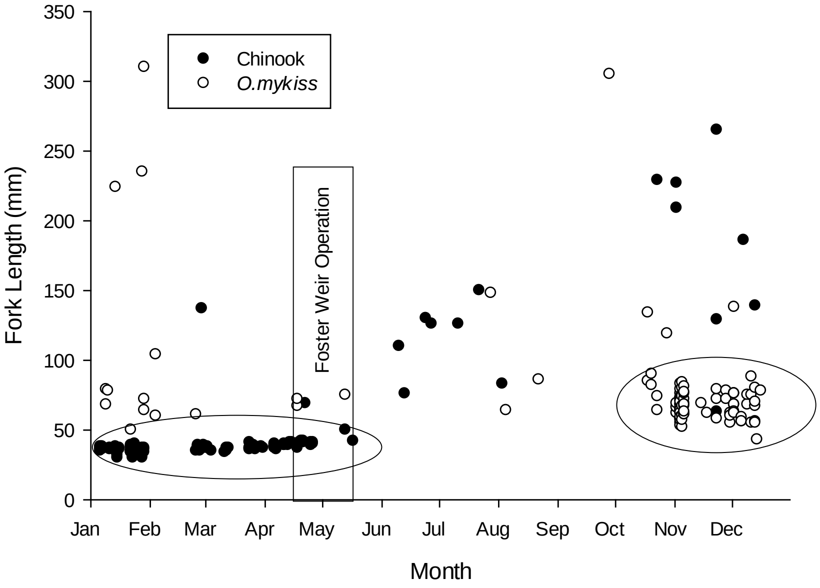

Figure 12. Fork lengths of unmarked juvenile spring Chinook salmon and *O. mykiss* captured in the rotary screw trap below Foster Dam, 2012. Circles denote subyearlings of both species and corresponding dam passage periods. Rectangle represents current operation timing for the Foster Dam fish weir.

Table 4. Number of fish captured in the screw trap below Foster Dam summarized by species and month. Mk = fin-marked; Unmk = unmarked.

	Chinook		*O. mykiss*		Kokanee	Cutthroat	Yellow Perch	Bluegill	Crappie	Largescale Sucker	Dace	Northern Pikeminnow	Bass	Brook Lamprey	Redside Shiner
Month	Mk	Unmk	Mk	Unmk											
JAN	0	58	3	25	88	0	47	5	0	0	4	1	0	0	0
FEB	18	12	0	8	37	0	16	0	0	0	0	0	0	0	0
MAR	1	18	0	2	8	0	1	1	0	0	0	0	0	0	0
APR	0	31	17	11	10	0	24	0	0	0	0	0	3	34	0
MAY	0	2	0	1	0	0	6	0	0	0	1	0	1	5	0
JUN	0	4	5	0	0	0	18	3	0	0	2	2	0	10	0
JUL	0	1	5	1	0	0	6	0	0	0	2	0	0	1	1
AUG	0	1	3	2	0	1	5	1	0	0	0	0	0	0	2
SEPT	0	0	0	2	0	0	5	1	0	0	0	0	0	0	0
OCT	0	3	8	11	5	2	379	5	7	4	12	0	0	0	0
NOV	3	3	1	63	3	0	629	1,065	0	25	204	12	0	0	0
DEC	0	2	3	15	4	0	188	101	0	0	0	3	0	1	0
TOTAL	22	135	45	141	155	3	1,324	1,182	7	29	225	18	4	51	3

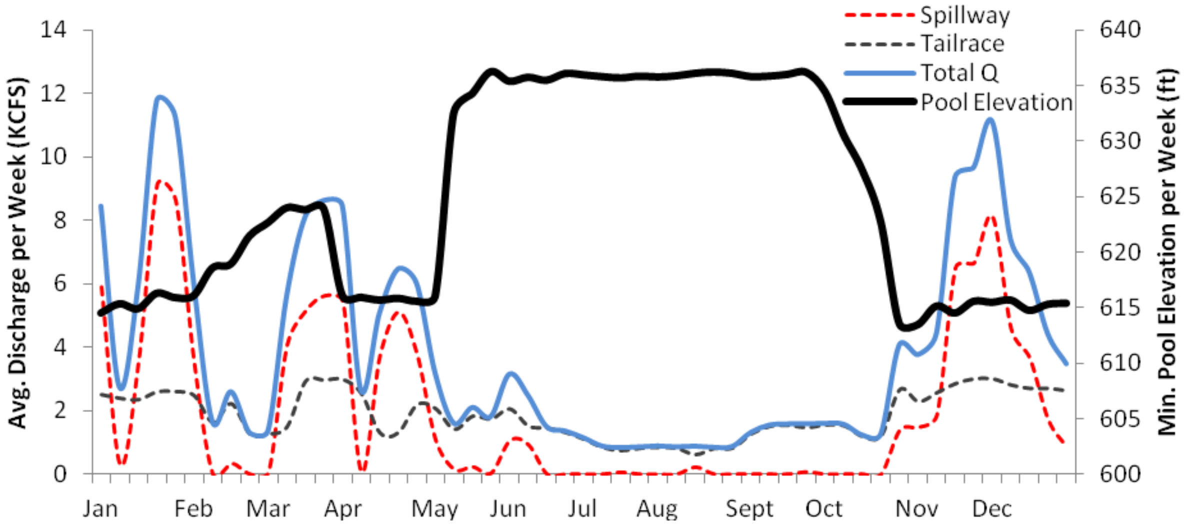

Figure 13. Foster Dam discharge (Q) and reservoir pool elevation, 2012. Discharge is reported as the weekly average and pool elevation is reported as the minimum elevation for each week.

Middle Fork Willamette River- We operated the Middle Fork Willamette (MFW) River trap upstream of Lookout Point Reservoir from February 15 through November 25, 2012. The trap fished for 241 days and captured 646 Chinook salmon subyearlings and 5 yearlings. We PIT-tagged 36 juveniles in the MFW trap and an additional 177 in the North Fork Middle Fork Willamette River in September while seining. The peak of the fry migration was February through June (Figure 14), and the median migration date was April 12 (Appendix B; Table B2). The size range for subyearlings was 31-129 mm FL (Figure 15). The previous year (2011) we captured a large number of subyearlings near the beginning of January (mean 34 mm FL), presumably due to increased flows that were pushing newly emerged fry downstream. In 2012 we did not begin fishing the trap until mid-February, but no high discharge events occurred in January. The mean size of fry captured in February in the MFW was 36 mm FL. Capture of juvenile Chinook salmon immediately subsequent to trap deployment, and the larger average size of subyearlings captured suggests that we missed some of the early emergent juveniles migrating past the trap site, and may have slightly influenced the median migration date observed in 2012.

Fish captured in the Middle Fork Willamette trap upstream of Lookout Point Reservoir exhibited greater variation in fork length than any of the other trapping sites (Figure 16). As mentioned in our previous report (Romer et al. 2012), several factors may contribute to the prolonged subyearling migration timing, and large variation in size of migrants. First, the trap was located 58 km from the furthest known upstream spawning area in the North Fork Middle Fork Willamette River, where most of the spawning in this sub-basin takes place. This is 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 before migrating downstream. Finally, trap catch was confounded by juvenile Chinook salmon (marked and unmarked) emigrating out of Hills Creek Reservoir. These variables, along with the higher temperatures, lend insight as to why fish captured in the MFW trap were larger than their counterparts rearing in the other sub-basins (Figure 16). Fish grow more rapidly in Lookout Point Reservoir (Romer et al. 2012) than in the other reservoirs discussed in this report and it is possible that the two large fish captured in late September (~240 mm, Figure 15) may be age-2 migrants from Hills Creek Reservoir, or they may be yearling fish that reared in Lookout Point and were moving upstream during the spawning season to search for mating opportunities. Similarly, the precocious male denoted by the circle in Figure 15 (168 mm) may have been a fast growing, subyearling, reservoir-reared fish rather than a yearling. All three of these larger fish had copepods present on their gills which is often indicative of reservoir rearing (Monzyk et al. 2012, 2013).

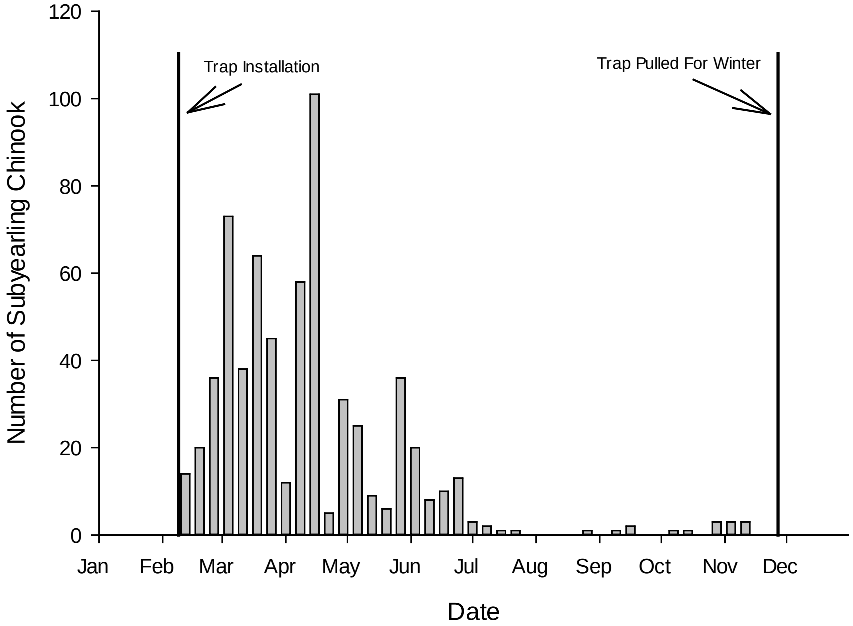

Figure 14. Weekly abundance of subyearling spring Chinook salmon captured in the Middle Fork Willamette trap upstream of Lookout Point Reservoir, 2012.

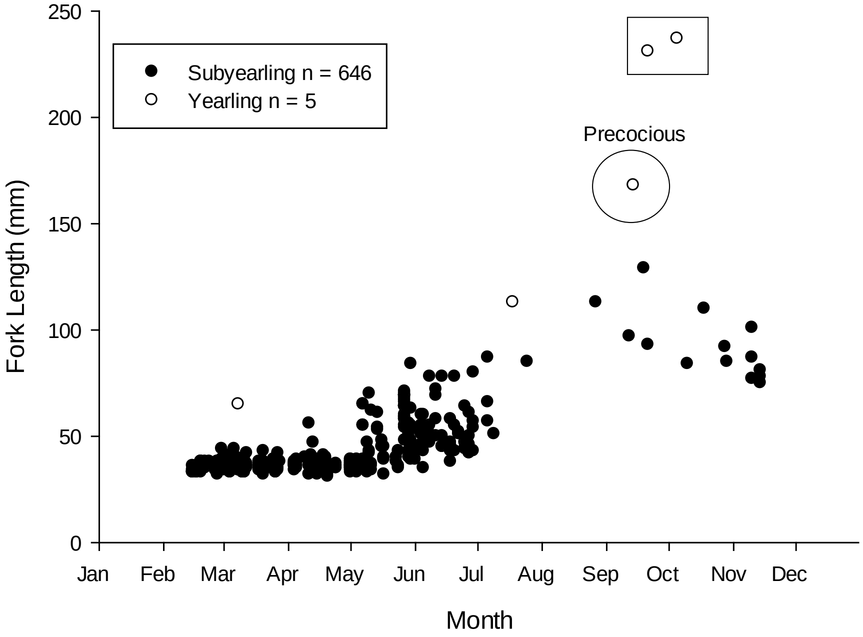

Figure 15. Fork length of subyearling and yearling Chinook salmon collected in the Middle Fork Willamette trap, 2012. Circled dot represents a male fish that was milting at the time of capture. Rectangle denotes two very large fish that may have been age-2 fish migrating from Hills Creek Reservoir or yearlings that swam upstream from Lookout Point Reservoir.

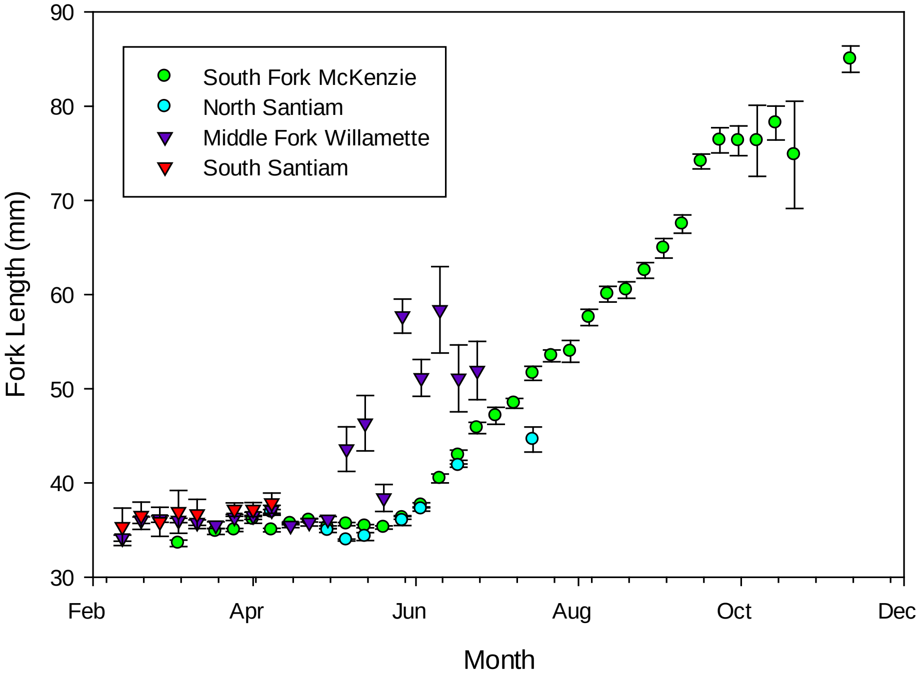

Figure 16. Comparison of growth for subyearling spring Chinook salmon at each upstream screw trap location, 2012. Data were summarized by week, excluding weeks when < 5 juveniles were captured. Error bars represent the standard error.

Below Lookout Point Dam- Personnel from USACE operated a 2.4-m screw trap below Lookout Point Dam from January 5 to October 30, 2012. The trap captured 56 hatchery and 156 unmarked juvenile Chinook salmon (subyearling and yearling). The trap was removed on October 30 to repair damages and was not re-deployed until January 2013. Catch included four fry; the first was collected April 26 and the other three on May 1 (mean 40 mm FL), in contrast to 2011 when the first fry were collected in February. Capture numbers for Chinook salmon 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, bass, rainbow trout, cutthroat trout, walleye *Sander vitreus*, black and white crappie *Pomoxis* spp., sculpin *Cottus* spp., dace *Rhinichthys* spp., pumpkinseed and bluegill, redside shiner *Richardsonius balteatus*, sucker, and bullhead (Table 5). This trap was removed prior to increased discharge from both the spillway and through the turbines associated with lowering the reservoir in November and December (Figure 17). This period is typically when the highest abundance of all species are captured below Lookout Point Dam (Keefer et al. 2012).

Table 5. Number of fish captured in the screw trap below Lookout Point Dam summarized by species and month. Mk = fin-marked; Unmk = unmarked.

	Chinook		Rainbow Trout		Northern Pikeminnow	Bass	Crappie	Pumpkinseed & Bluegill	Sculpin	Largescale Sucker	Redside Shiner	Unknown
Month	Mk	Unmk	Mk	Unmk								
JAN	54	27	0	0	0	0	11	0	2	3	6	0
FEB	0	0	0	0	1	0	1	0	5	0	0	0
MAR	2	3	0	0	0	0	0	0	8	9	2	0
APR	0	4	0	0	1	1	1	0	3	4	0	0
MAY	1	17	3	1	2	0	1	0	1	2	0	0
JUN	39	66	0	0	1	0	0	1	2	0	0	1
JUL	1	0	0	0	0	0	0	3	1	0	0	90
AUG	0	0	0	0	0	1	0	0	2	0	0	196
SEPT	0	0	0	0	0	0	5	0	6	0	0	2
OCT	1	0	0	0	2	1	11	61	16	2	0	0
NOV	Trap Removed											
DEC												
TOTAL	98	117	3	1	7	3	30	65	46	20	8	289

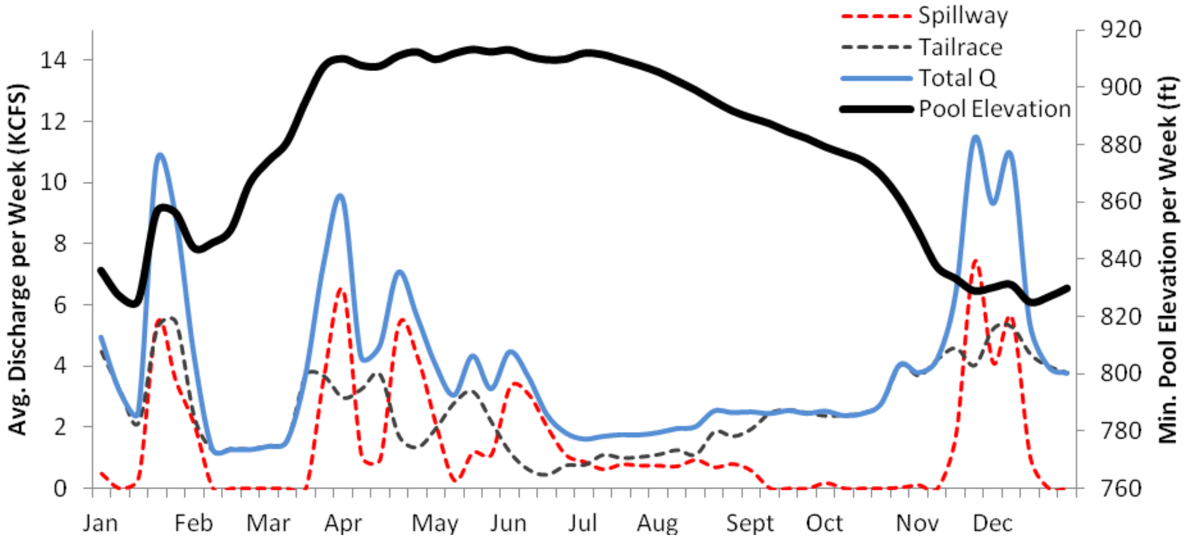

Figure 17. Lookout Point Dam discharge (Q) and reservoir pool elevation, 2012. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week.

On April 20, 46,000 genetically-marked hatchery fish were released near the head of Lookout Point Reservoir (Hampton boat ramp) and on May 23, an additional 50,000 PIT-tagged hatchery fish were released by ODFW as part of a paired release study (Friesen et al. 2013 *in prep*). Fish that were genetically marked did not receive an adipose fin clip and were indistinguishable from naturally-produced fish. Therefore, data from below Lookout Point Dam are not reported in terms of hatchery or wild fish, but were instead reported as marked and unmarked fish. Marked fish were those with an adipose clip or PIT tag. Dam discharge (Figure 17) was controlled from April through June to mimic the discharge from 2011 to maintain consistency and allow comparability for the paired release study between years. This spillway discharge resulted in an increased number of Chinook salmon captured below the dam in May and June (Table 5). Increased spill during summer months is non-typical of historical flow management regimes (Romer et al. 2012), and previously juvenile Chinook salmon in the Middle Fork Willamette River exited Lookout Point Reservoir between November and February (Keefer et al. 2011). The November - February outmigration period is consistent with data we have collected from below dams in other upper Willamette sub-basins.

South Fork McKenzie River- We operated the South Fork McKenzie trap upstream of Cougar Reservoir from February 28 to November 27, 2012 and the trap fished for 236 days. The peak in fry capture abundance occurred in the South Fork McKenzie from April through May (Figure 18), with a median migration date of May 16. 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; Monzyk et al. 2011; Bureau of Commercial Fisheries 1960). Unlike the traps upstream of reservoirs in the other sub-basins, the South Fork McKenzie trap collected subyearling juvenile Chinook salmon continuously from April through the end of September. Overall, we collected 6,482 Chinook salmon subyearlings, 6 yearlings, and PIT-tagged 897. Growth of the subyearling cohort upstream of the reservoir was not evident until the end of June (Figure 19).

The size of subyearling Chinook salmon ranged from 31 to 103 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. One albino fry was captured on June 4 with a fork length of 38 mm. Very few yearlings were captured upstream of the reservoir, and yearlings caught later in the year were precocious males that were milting. In addition, four of the five precocious males were infected with copepods, suggesting that they had spent time rearing in Cougar Reservoir. We classified these fish as yearlings in the upstream traps but it is just as likely that they were fast-growing subyearlings that reared in the reservoir and returned to the stream to reproduce. In addition, we also captured several milting, subyearling males below Cougar Dam in the same size range during the same period.

The Leaburg Dam Bypass on the McKenzie River provided our first opportunity to detect fish tagged in the South Fork McKenzie River. At Leaburg Dam, the middle roll gate was inoperable from January 19 through the end of the trapping season, and the bank on the south side of the river showed signs of significant erosion (EWEB, Lisa McLaughlin *pers. comm*). In response the Eugene Water and Electric Board opened the gate on the north side (closest to the bypass trap) which is suspected to decrease the smolt trapping efficiency at the Leaburg Bypass fish collector. After the north side roll gate was opened the Willamette Spring Chinook Project noticed an immediate decrease in the number of juvenile spring Chinook salmon captured in the bypass collector (Schroeder et al. 2013 *in prep.*). Therefore, fish that were tagged upstream in the South Fork McKenzie sub-basin (South Fork McKenzie River, Cougar Reservoir) had a reduced chance of being captured or detected at Leaburg Bypass for nearly the entire season (Appendix A; Table A4).

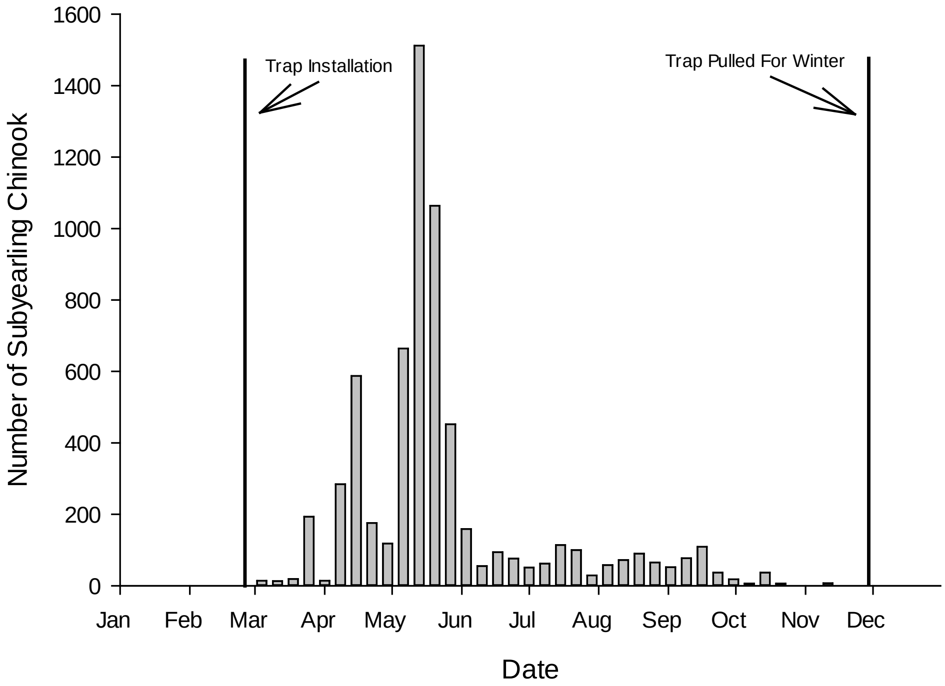

Figure 18. Weekly abundance of subyearling spring Chinook salmon captured in the South Fork McKenzie trap above Cougar Reservoir, 2012.

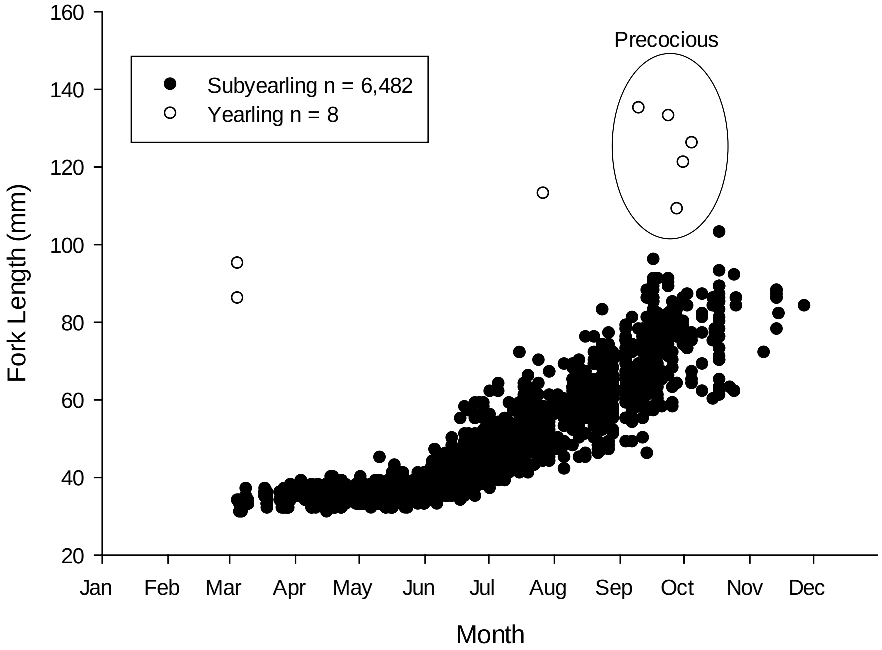

Figure 19. Fork length of subyearling and yearling Chinook salmon collected in the South Fork McKenzie trap above Cougar Reservoir, 2012. The circle represents yearling, precocious males that were milting at the time of capture.

Below Cougar Dam – We operated three rotary screw traps below Cougar Dam for a majority of the 2012 field season. Trap catch included 2,987 subyearling and 433 yearling unmarked Chinook salmon (Figure 21; Table 6). We captured 40 subyearling fry (< 50 mm FL) in the traps below Cougar Dam. Twenty-six fry were collected in the tailrace traps between March 27 and April 23, and 14 were collected in the RO trap between April 23 and June 25. The first subyearling was collected in the screw trap upstream of Cougar Reservoir on March 5, 2012. This suggests that though migration is delayed, some fry traversed the reservoir and survived passage through both routes. Fry dam passage occurred following increased total discharge (Q) from Cougar Dam early in the spring (Figure 22). For verification, genetic samples collected from fry caught in previous years below the dam indicate that these fry were progeny from adults passed upstream of the reservoir (Banks et al. 2012). Most subyearlings were collected in the fall from the RO trap coinciding to increase discharge through the RO and decreasing reservoir elevations (Figure 20 and22).

Yearling catch may be underrepresented because there were several instances early in 2012 when traps below Cougar Dam were unable to fish (Figure 3). Between January 23 and January 30, 2012 the RO discharge averaged 3,490 ft^3/s and we were unable to operate our trap due to unsafe conditions. Previous work demonstrated that large numbers of spring Chinook salmon exit the reservoir in January and February, with peak cohort outmigration occurring between November and February (Romer et al. 2012; Zymonas et al. 2012; Taylor 2000). Therefore, we suspect that a large number of yearlings exited the reservoir at this time. Results from the USGS radio tagging study confirmed that a pulse of radio tagged fish exited the reservoir during this period (Beeman et al. 2013 *in prep*). In addition, from February 3 – March 7 we did not operate the traps below Cougar Dam while safety modifications were implemented.

On November 21, 2012, during a planned hydropower unit shutdown, the number one regulating outlet was opened under automatic control (as designed), but the limit switch to stop the gate at the desired height malfunctioned. Consequently, the RO gate opened to the fully open position (~12 ft). Using data from downstream USGS flow meters, flows of about 7,000 ft^3/s were sustained for 40 minutes before returning to normal (~ 3,000 ft^3/s). This unexpected pulse in flow resulted in an estimated 3 ft rise in the river level immediately downstream from Cougar Dam, and damaged our cabling for the screw trap in the regulating outlet channel. The screw trap was unable to fish from November 21 – 29 until infrastructure was repaired and the trap was re-deployed on November 30, 2012. This event occurred during the peak subyearling outmigration (Figure 20), likely resulting in an underrepresentation of catch.

Peak outmigration for a cohort of Chinook salmon occurs between November and February. Although fish are from the same cohort, the age class (subyearling, yearling) is determined by the calendar year. For example, juveniles from the 2010 brood year that outmigrated in November and December 2011 were considered subyearlings and comprised a majority of the fall outmigrants. Juveniles from the same cohort comprised the majority of the winter/spring yearling migrants in 2012 (Appendix C; Table C1). Although winter/spring outmigrants were primarily yearlings, some older fish (>200 mm FL) and subyearling fry (<50 mm FL) were also captured during this period (Figure 21).

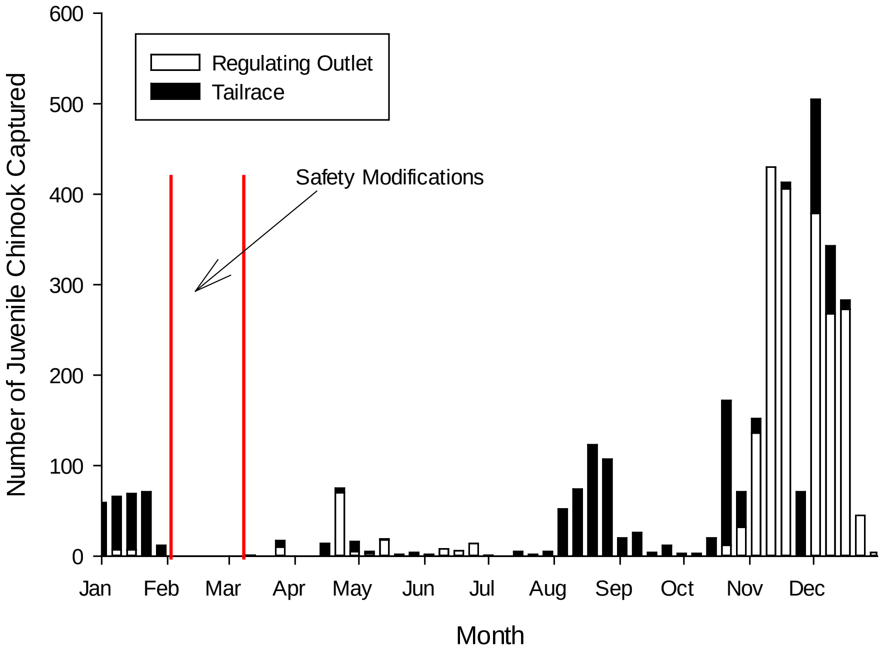

Figure 20. Weekly abundance of unmarked juvenile spring Chinook (subyearling and yearlings) captured below Cougar Dam in rotary screw traps, 2012.

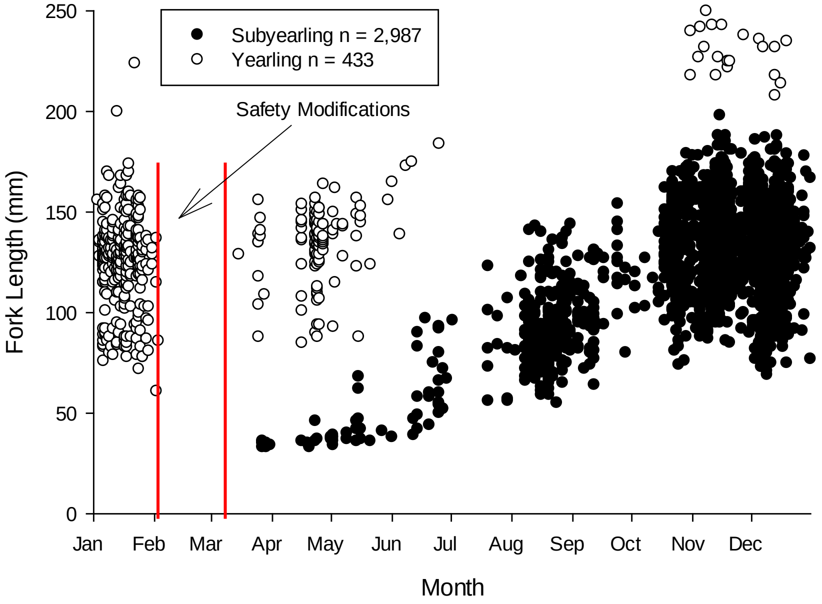

Figure 21. **Relationship between fork length and capture date for natural-origin juvenile Chinook salmon below Cougar Dam, 2012**.

Table 6. Number of fish captured in the screw trap below Cougar Dam summarized by species and month. Unmk = unmarked.

Month	Chinook Unmk	Rainbow Trout Unmk	Cutthroat	Mountain Whitefish	Bass	Dace	Brook Lamprey	Sculpin
JAN	288	2	1	2	0	1	1	0
FEB	4	0	0	0	0	0	0	0
MAR	18	8	0	0	0	0	0	0
APR	88	4	0	0	0	1	0	0
MAY	45	3	1	0	0	1	0	3
JUN	32	3	0	0	0	3	0	1
JUL	12	6	0	0	0	13	0	5
AUG	357	5	1	1	1	18	0	4
SEPT	62	10	2	1	0	0	0	8
OCT	253	4	3	0	0	0	1	2
NOV	1,081	5	0	2	1	3	0	1
DEC	1,180	4	0	8	1	13	1	0
TOTAL	3,420	54	8	14	3	53	3	24

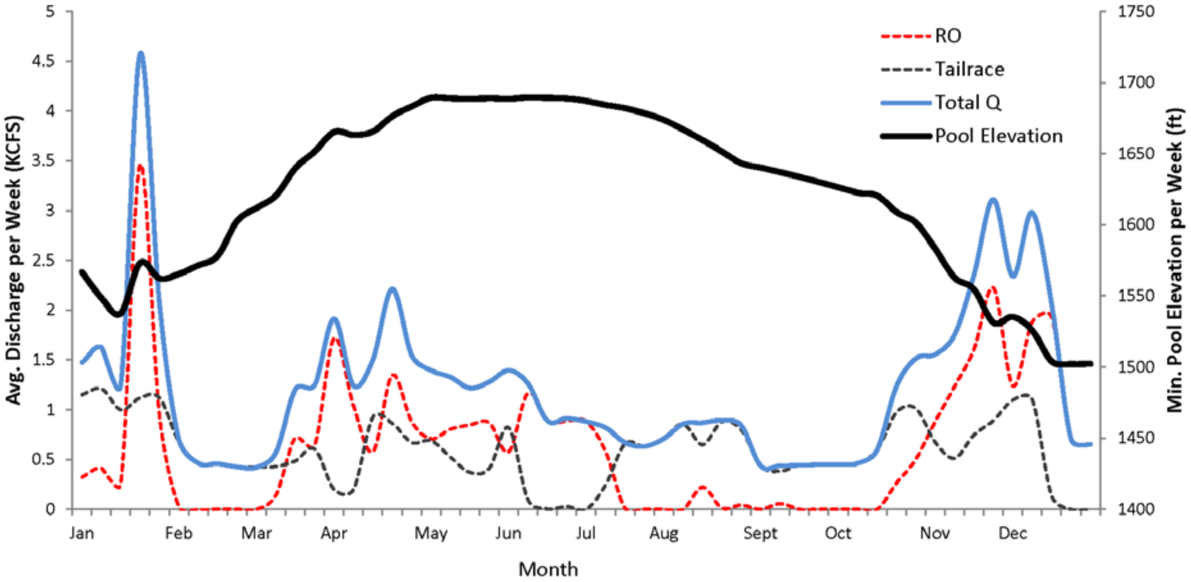

Figure 22. Cougar Dam discharge (Q) and reservoir pool elevation, 2012. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week.

Special Operations below Cougar Dam

<u>Day vs. Night Dam Passage</u> – In December, when both the RO and turbines were running continuously (day and night), we captured juvenile Chinook salmon in both the RO and turbine tailrace traps. Although the number of fish captured in the tailrace was considerably less, 15% of the total catch came from the turbine tailrace traps (Figure 23). This illustrates that when both routes were operating at night, fish were captured in both traps. In contrast, during the November special operations when only the RO was running at night (turbines off at night) and

turbines were running during the day, only 0.3% of the total catch was from the tailrace traps suggesting that nearly all of the fish were passing through Cougar Dam at night. Corroborative evidence from the USGS radio tagging study (Beeman et al. 2013) confirmed that a large majority of tagged juveniles (> 90%) also exited Cougar Dam at night in December.

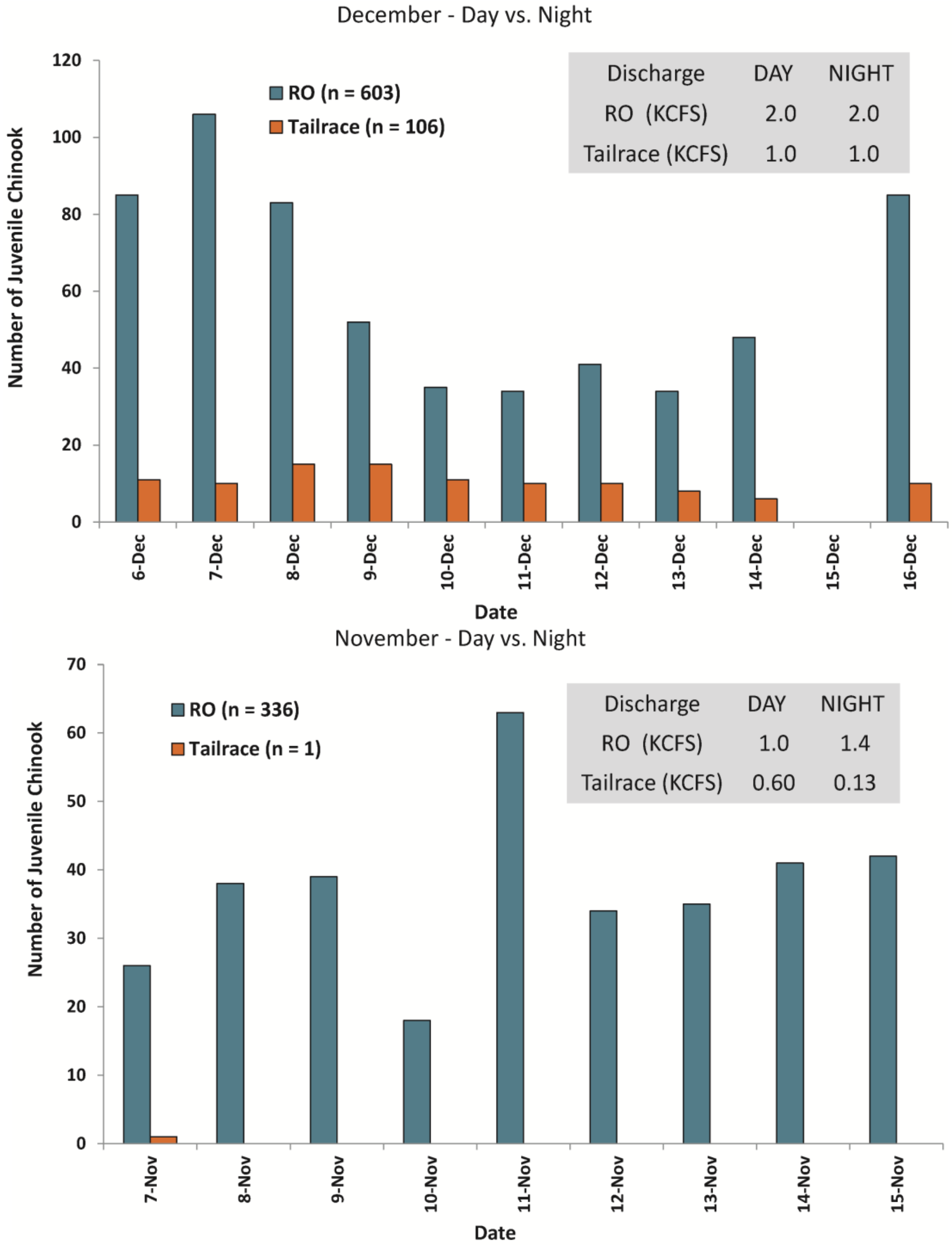

Figure 23. Number of juvenile Chinook salmon captured during two special dam operations in November and December, 2012. December 6-16 shows catch below Cougar Dam when discharge from the tailrace and RO was held constant. November 7-15 shows catch below Cougar Dam when only the RO was operating at night.

<u>Deeper Drawdown</u> – In mid-December, the Cougar Reservoir pool level was drawn down below the typical minimum pool elevation (Figure 24). Turbines were not operated after the reservoir pool level descended below 1,525 ft, and all subsequent flow was discharged through the regulating outlet. The general pattern for fish leaving the reservoir appeared the same as in previous years, with the number of fish captured below the dam decreasing by the end of December, and we were unable to assess whether the 'deeper drawdown' caused an increase in the of fish leaving the reservoir. However, it appeared that the deeper drawdown may have advanced the timing of juveniles exiting the dam. As the reservoir level dropped below typical minimum pool elevation, where it is no longer possible to run the turbines and all flow was directed out of the RO, we observed an increase in the number of fish exiting the reservoir. This increase in fish exiting the reservoir occurred despite the overall decrease in discharge during this period.

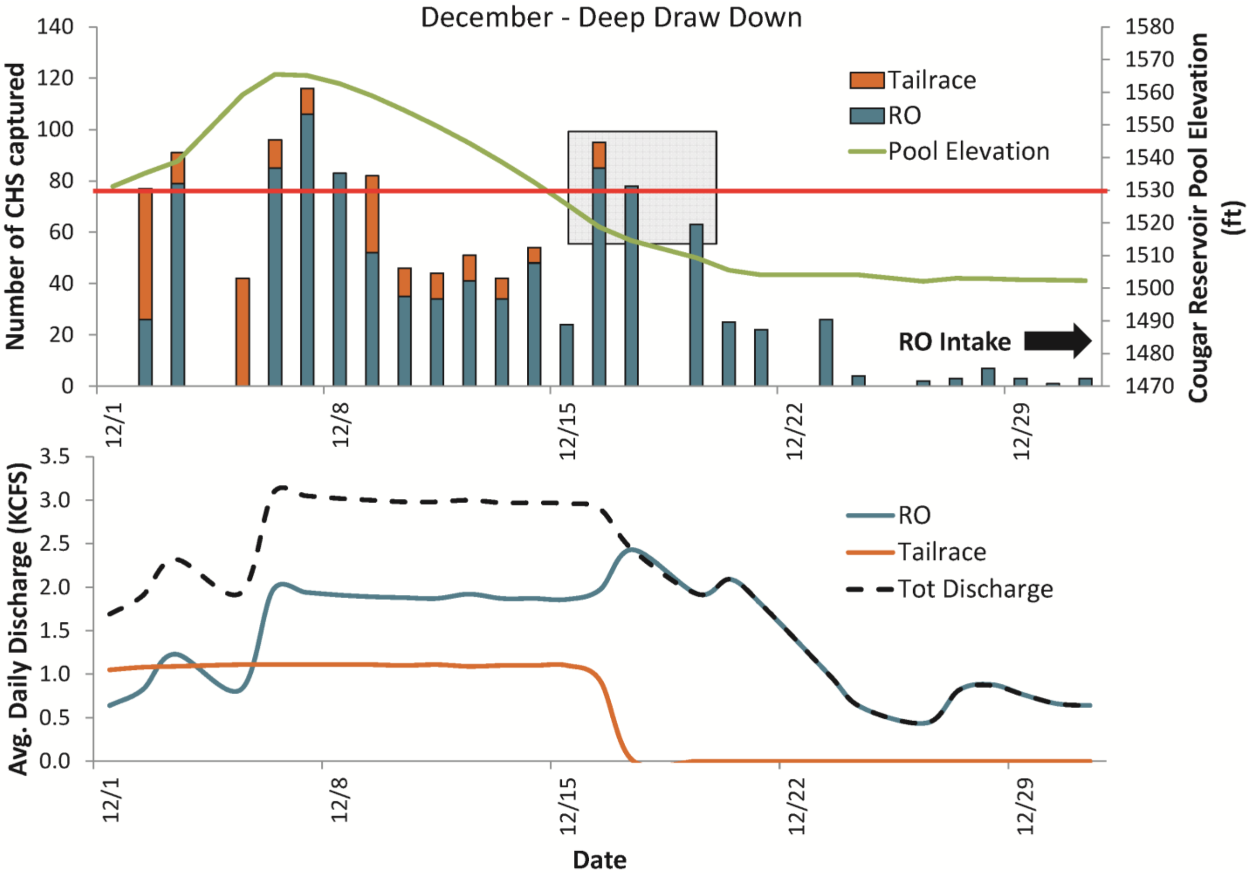

Figure 24. Number of Chinook salmon captured in the tailrace and regulating outlet (RO) channels below Cougar in December, 2012 (top panel) and corresponding average daily discharge from each route (bottom panel). The grey box highlights the period of interest when the discharge from the tailrace was stopped and the reservoir pool elevation dropped below the typical low pool level for Cougar Reservoir under the standard rule curve (designated by the red line). The green line represents the average daily pool elevation for Cougar Reservoir during December, 2012. The black arrow indicates the elevation of the intake for the RO.

Injury Summary below Cougar Dam

Percent Occurrence for Each Injury - Proportions of injury types observed between exit routes were evaluated using a z-test to identify differences in proportions greater than would be expected if there were no difference between routes. Live fish with no observable injuries exited the turbine tailrace at a significantly higher proportion (58.7%) than the RO (14.9%; $z = 22.82$, $p < 0.001$; Table 7). This does not infer that the tailrace is a safer passage route for fish. It is plausible that fish exiting the turbines are either killed or escape relatively unharmed, with low occurrence of intermediate degrees of injury. A potential confounding factor is that the cause of death for fish captured exiting each route is different, and the method of mortality may be related to the efficiency of the screw trap. For example, if fish are killed passing through a turbine they may be torn, cut, 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. 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 (Romer et al. 2012).

Injuries observed on a significantly higher proportion of fish captured in the RO channel than in the tailrace were hemorrhaging to the eye ($z = 3.40$, $p < 0.001$), gas bubble disease ($z = 15.50$, $p < 0.001$), opercle damage ($z = 4.60$, $p < 0.001$), and severe descaling ($z = 6.69$, $p < 0.001$); a mixture of both mechanical damage and barotrauma injury categories. Injury codes more frequently observed in the tailrace were descaling less than 20% ($z = 2.61$, $p = 0.009$), bleeding from vent ($z = 1.98$, $p = 0.049$), tears and scrapes ($z = 6.72$, $p < 0.001$) and severed bodies ($z = 3.67$, $p < 0.001$), which are primarily associated with mechanical damage. Of the individual fish captured below Cougar Dam exiting the tailrace with one or more injury, 5.6% had more than two injury codes whereas 18.0% of the fish exiting the RO had more than two injury codes. This shows that a higher proportion of juvenile Chinook salmon captured in the RO channel had three or more of the injuries shown in Table 7 when compared to those captured in the tailrace ($z = 6.41$, $p < 0.001$). Interestingly, 310 subyearlings captured below the dam were also noted as infected with fungus in 2012; this was not observed in previous years. Reports of the fungus started in August in both upstream and below-dam screw traps.

Table 7. Number and percent occurrence of injury types recorded in the regulating outlet and tailrace channels below Cougar Dam, 2012. NXI and MUNK fish percentages were calculated from the total number of fish captured and were removed from subsequent analysis as they exhibited no external injury. Asterisks denote significant differences in observed vs. expected injury rates (z-test; *P* < 0.05).

		Regulating Outlet		Tailrace	
Description of Injury	**Injury Code**	**Number**	**Percent**	**Number**	**Percent**
Live fish with no external injury	NXI*	197	14.9	696	58.7
Mortality with no external injury	MUNK	7	0.5	11	0.9
Moribund (barely alive)	MBD	55	4.9	21	4.4
Descaling < 20%	DS<2*	659	58.9	316	66.0
Bloated	BLO	48	4.3	19	4.0
Bloody Eye (hemorrhage)	EYB*	84	7.5	14	2.9
Eye Missing	EYM	11	1.0	6	1.3
Bleeding from Vent	BVT*	18	1.6	16	3.3
Fin Blood Vessels Broken	FVB	103	9.2	48	10.0
Gas Bubble Disease (fin/eye)	GBD*	475	42.5	16	3.3
Pop Eye (eye popping out of head)	POP	12	1.1	3	0.6
Head Injury	HIN	42	3.8	14	2.9
Opercle Damage	OPD*	98	8.8	11	2.3
Body Injury (tears, scrapes)	TEA*	39	3.5	60	12.5
Bruising	BRU	44	3.9	27	5.6
Hole Behind Pectoral Fin	HBP	14	1.3	11	2.3
Descaling > 20%	DS>2*	303	27.1	56	11.7
Head Only	HO	0	0.0	0	0.0
Body Only	BO*	2	0.2	10	2.1
Head Barely Connected	HBO	2	0.2	4	0.8
Total fish with ≥ 1 injury		1,118		479	

Barotrauma vs. Mechanical Damage - The type of injury, and whether it was associated with barotrauma or mechanical damage was also of interest. If no injury code was noted, or if the code was not believed to be associated directly with dam passage fish were not included in this summary. It was possible for one fish to have injuries associated with both mechanical and barotrauma. Of the fish that were captured with injuries believed to be associated with dam passage, a higher percentage of them were found dead in the tailrace trap. Fish captured in the tailrace also had a higher instance of injury associated with mechanical damage. Barotrauma was more prevalent in the regulating outlet, as were fish showing injuries related to both mechanical and barotrauma injury (Table 8).

Table 8. Percent of fish with injury codes associated with barotrauma or mechanical damage in the regulating outlet and tailrace channels below Cougar Dam, 2012.

	Regulating Outlet	**Tailrace**	**Total**
	(n = 850)	(n = 241)	(n = 1,091)
Injury Category	Percent	Percent	Percent
Barotrauma	74.4	43.6	67.6
Mechanical	52.1	69.2	55.9
Baro+Mech	26.5	12.9	23.5
Disposition			
Dead	32.8	42.3	34.9
Live	67.2	57.7	65.1

Abundance Estimates of Outmigrants

The South Fork McKenzie trap upstream of Cougar Reservoir – The South Fork McKenzie trap was the only trapping site where we captured sufficient numbers of fish to provide a precise abundance estimate. Weekly trap efficiencies ranged from 1.8 to 18.9% with a weighted annual TE of 2.9 % for 2012. We estimated 228,241 (95% CI ± 34,715) subyearlings migrated past our screw trap on the South Fork McKenzie River and into Cougar Reservoir between January and December 2012. The vast majority (88%) of subyearlings moved into Cougar Reservoir as fry from April through June. This is a 50% increase from the 2010 BY estimate of 152,159 subyearlings migrating past the trap (Table 9). The number of adult females outplanted upstream of the reservoir was nearly the same for these two years (Appendix B; Table B1) but more redds were observed contributing to the 2011 BY. In addition, the highest flow recorded early in 2012 while eggs from the 2011 BY were still in the gravel was 4,980 ft^3/s, whereas in 2011 flows reached 7,060 ft^3/s during the same period in mid-January which may have decreased survival or pushed 2010 BY juveniles downstream past our trap during high flow. Recently there has been an increase in the number of redds observed downstream of the South Fork McKenzie screw trap (Table 9). Progeny from these redds are not included in the abundance estimate, so it is likely that recent abundance estimates were underestimated. We do not know the survival rate of the eggs to emergence for these redds near the head of the reservoir, but a contribution of 12% and 13% of the overall redds counted for the 2011 and upcoming 2012 BY respectively may be significant if the trend persists.

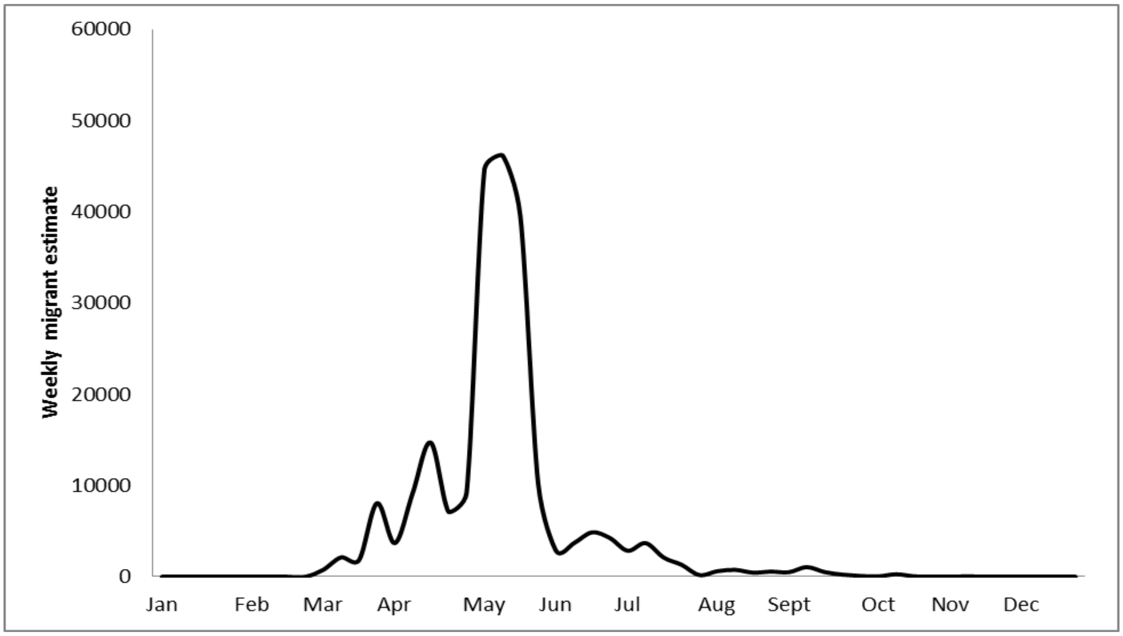

Figure 25. Weekly population estimates for subyearling spring Chinook salmon migrating past the South Fork McKenzie trap in 2012.

Table 9. Annual estimates of the number of juvenile Chinook salmon migrating past the South Fork McKenzie screw trap upstream of Cougar Reservoir.

Brood Year (BY)	Abundance Est.	95% CI	Number of BY Females	Total Number of Redds (peak)	Number of Redds below trap
2009	685,723	±72,519	629	274	< 5
2010	152,159	±26,665	320	190	--
2011	228,241	±34,715	336	241	29
2012	In Progress	--	448	249	33

Recommended Future Directions

Our data demonstrates that subyearlings are the prominent year class emigrating from streams into WVP reservoirs, including juvenile *O. mykiss* into Foster Reservoir. These fish grow larger and more quickly in the reservoirs and this could result in increased survival to adulthood (Claiborne et al. 2011; ISRP 2011). However, the benefit of reservoir rearing must be weighed against potential risks such as residualism and larger individuals incurring higher mortality when passing through dams (Taylor 2000; Normandeau 2010; Keefer et al. 2011; Zymonas et al. 2012 *in review*). Reservoir-rearing juveniles are also exposed to predation and copepod infections (Monzyk et al. 2012, 2013), though both risks have yet to be fully assessed. Current management strategies (e.g., at-dam passage structures, interim dam operations) aimed at providing safe passage through reservoirs and dams for earlier life-stages will help to maintain the diversity of life-history strategies, specifically those that reach the Columbia River estuary in the spring as subyearlings (Mattson 1962; Schroeder et al. 2007). Passage survival could be improved by passing more fish at a smaller size earlier in the year. This strategy would also mitigate for the potential risks of copepod infection and predation associated with reservoir rearing until the impact of these risks are better understood.

The deep drawdown implemented at Cougar Reservoir in December of 2012 may have advanced the dam passage timing of juvenile Chinook salmon by several weeks, although the pattern of emigration from the reservoir remained the same as in previous years with capture numbers dropping off near the end of December. It would be useful to attempt deep drawdown earlier in the fall to determine whether large numbers of fish would exit the reservoir earlier in the year, thus increasing cohort dam passage efficiency and reducing the likelihood of residualism. Lower reservoir pool elevation earlier in the year may also decrease the effects of barotrauma for a larger proportion of fish entrained for passage.

The Foster Dam fish weir is currently being operated from April 15 – May 15 each year, a period when it appears few subyearling Chinook salmon or juvenile *O. mykiss* are leaving Foster Reservoir. We suggest operating the weir throughout the summer and into the fall may improve juvenile *O. mykiss* passage through the reservoir. We will also increase our efforts to PIT-tag fish in Foster Reservoir in 2013, and resulting downstream detections should provide additional information on *O. mykiss* migration and behavior patterns in the South Santiam River and throughout the Willamette River basin.

We will continue to record and assess injury types below dams in 2013. With an additional year of data we will have the ability to analyze these data in greater detail. We also plan to take samples of the fungus observed in 2012 if there is a reoccurrence in 2013 for identification by pathologists. With the high infection rates of copepods on reservoir rearing fish it seems logical to determine whether these parasites affect the ability of smolts to transition to saltwater or decrease individual fitness, ultimately affecting survival.

We will continue to operate rotary screw traps at the same locations in 2013. Continued monitoring will provide a more complete picture of outmigration both upstream and downstream of WVP dams. Long term monitoring data generated from this project allows researchers to track changes in migration and survival as it relates to the constantly changing environmental variables among years, will help to assess the myriad of reservoir and dam passage options proposed for juvenile fish in the upper Willamette basin, and help evaluate the success of the current adult outplanting program upstream of WVP reservoirs.

Acknowledgments

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Appendices

Appendix A. PIT tag information.

Table A1. Number of yearling and subyearling Chinook salmon PIT-tagged at each sampling location in 2012.

Location	Subyearling	Yearling	Total
SF McKenzie[a]	890	7	897
Cougar Reservoir[b]	488	44	532
Cougar Tailrace	24	284	308
Breitenbush River[c]	0	0	0
North Santiam River	13	12	25
Detroit Reservoir	0	0	0
Detroit Tailrace	0	7	7
Middle Fork Willamette[d]	34	1	35
NF Middle Fork Willamette[e]	177	0	177
Lookout Point Reservoir	1	0	1
South Santiam River	12	0	12
Foster Tailrace	2	0	2
Grand Total	1,641	355	1,996

[a] 470 of the subyearlings were tagged while seining

[b] Five age-2 fish that were tagged but not included in table

[c] No adult fish were outplanted in the Breitenbush in the fall of 2011 so we did not sample or tag

[d] One hatchery CHS was tagged, not included in table.

[e] All 177 subyearlings were tagged while seining

Table A2. Number of juvenile Chinook salmon PIT tagged by the Willamette Reservoir Research Project 2010-2012.

Location	2010	2011	2012	Total
South Fk. McKenzie R.	83	615	897	1,595
Cougar Reservoir	440	547	537	1,524
Cougar Tailrace	-	1,072	308	1,380
Breitenbush R.	8	111	0	119
North Santiam R.	231	184	25	440
Detroit Reservoir	-	58	0	58
Detroit Tailrace	-	66	7	73
Middle Fk. Willamette	76	36	36	148
NFMF Willamette	109	78	177	364
Lookout Point Reservoir	83	72	1	156
South Santiam R.	67	1	12	80
Foster Tailrace	-	2	4	6
Grand Total	**1,097**	**2,842**	**2,004**	**5,943**

Table A3. Number of juvenile *O. mykiss* PIT tagged by the Willamette Reservoir Research Project in the South Santiam sub-basin, 2011-2012.

Location	2011	2012	Total
South Santiam	205	321	526
Foster Tailrace	-	49	49
Grand Total	**205**	**370**	**575**

Table A4. Juvenile Chinook salmon PIT-tagged upstream of Willamette Valley Project dams 2010-2012 and subsequently detected at downstream recapture or interrogation sites. Year refers to the year the fish was tagged. Fish detected and recaptured at Leaburg were only counted one time.

Tagging Location	Recap/Interrogation Location	Number Recaptured		
		2010	2011	2012
North Santiam River	Willamette Falls	**3**	**2**	**0**
	Columbia River Trawl	**1**	0	0
Breitenbush River	Willamette Falls	0	**2**	NA
Detroit Reservoir	Willamette Falls	0	**1**	**0**
Detroit Tailrace	Willamette Falls	**0**	**1**	0
South Santiam River	Willamette Falls	**4**	0	0
SF McKenzie River	Cougar Reservoir	0	**4**	0
	Cougar Tailrace	0	**10**	**11**
	Leaburg	0	**15**	**12**
	Walterville	NA	0	**9**
	Willamette Falls	0	**2**	0
	Columbia River Trawl	0	**1**	0
Cougar Reservoir	Cougar Reservoir	**2**	**6**	**9**
	Cougar Tailrace	**5**	**5**	**8**
	Leaburg	**23**	**5**	**11**
	Walterville	NA	**2**	**7**
	Willamette Falls	**3**	**2**	**0**
	Columbia River Trawl	0	0	0
Cougar Tailrace	Leaburg	0	**204**	**48**
	Walterville	NA	**23**	**2**
	Willamette Falls	0	**12**	**4**
	Columbia River Trawl	0	**1**	0
	East Sand Island	0	0	**1**
Middle Fork Willamette River	Lookout Point Reservoir	0	**2**	0
	Willamette Falls	0	0	0
Lookout Point Reservoir	Willamette Falls	**1**	0	0

Appendix B. Basin-wide information.

Table B1. Number of adult female spring Chinook salmon outplanted upstream of Willamette Valley reservoirs 2009-2012 (Cannon et al. 2010, 2011; Sharpe et al. 2013; ODFW, unpublished data).

Reservoir	River	Year	♀Outplants
Detroit	Breitenbush	2009	36
		2010	397
		2011	0
		2012	23
	North Santiam	2009	111
		2010	746
		2011	63
		2012	98
Foster	South Santiam	2009	172
		2010	231
		2011	597
		2012	444
Cougar	South Fork McKenzie	2009	629
		2010	320
		2011	336
		2012	448
Lookout Point	North Fork Middle Fork Willamette	2009	361
		2010	573
		2011	787
		2012	1,208

Table B2. Yearly median migration date for subyearling Chinook salmon migrating past Willamette Reservoir Research Project traps.

	Median Migration Date		
Location	2010	2011	2012
North Santiam	-	May 6	May 14
Breitenbush	-	Mar 8	-
South Santiam	-	-	Mar 7
South Fork McKenzie	May 1	May 16	May 16
Middle Fk. Willamette	-	Mar 28	Apr 13

Appendix C. Below Cougar Dam.

Table C1. Number of juvenile Chinook salmon captured each month below Cougar Dam partitioned by brood year (BY; 2009-2012). Data are summarized on a 22 month scale corresponding to the typical reservoir exit timing for the entire cohort. Asterisks denote the last month of data collection available.

Life Stage	Month	2009 BY	2010 BY	2011 BY	2012 BY
Fry (<60 mm)	Mar	0	13	6	0
Fry (<60 mm)	Apr	9	1	6	118
Fry (<60 mm)	May	1	1	23	60
Fry/Subyearling	Jun	127	9	25	218
Fry/Subyearling	Jul	0	17	12	17*
Fry/Subyearling	Aug	80	38	380	
Subyearling	Sep	26	19	60	
Subyearling	Oct	60	90	250	
Subyearling	Nov	905	942	1,068	
Subyearling	Dec	2,155	125	1,174	
Yearling	Jan	373	288	6	
Yearling	Feb	72	4	2	
Yearling	Mar	62	12	2	
Yearling	Apr	242	82	35	
Yearling	May	153	20	71	
Yearling	Jun	48	5	26	
Yearling	Jul	10	0	3*	
Yearling	Aug	0	0		
Yearling	Sep	1	0		
Yearling	Oct	0	2		
Yearling	Nov	17	13		
Yearling	Dec	2	6		
	Total	4,343	1,687	3,149	413