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JUVENILE SALMONID OUTMIGRATION MONITORING AT WILLAMETTE VALLEY PROJECT RESERVOIRS

Prepared for
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Summary

The goal of this project was to provide information regarding fish species composition, abundance, timing and size of fish entering and exiting Willamette Valley Project (WVP) reservoirs that can be used to evaluate options for developing downstream passage for juvenile salmonids *Oncorhynchus* spp. at upper Willamette River reservoirs. We present data from screw trap operations above and below USACE project dams during 2015. Traps upstream of reservoirs were located on the North Santiam and Breitenbush rivers above Detroit Reservoir, the South Santiam River above Foster Reservoir, the South Fork McKenzie River above Cougar Reservoir, the Middle Fork Willamette River above Hills Creek Reservoir (MFW-HC), and the North Fork Middle Fork Willamette River (NFMF) above Lookout Point Reservoir. Traps below dams were located below Big Cliff, Foster, and Cougar dams. We also report results from traps operated by USACE personnel located below Lookout Point and Fall Creek dams (Figure 2).

The objectives of this project were to 1) provide information on migration timing and size of juvenile spring Chinook salmon *O. tshawytscha* and winter steelhead *O. mykiss* entering WVP reservoirs; 2) provide information on emigration timing and size of juvenile salmonids exiting the reservoirs; 3) estimate the abundance of juvenile Chinook salmon entering and exiting reservoirs where trap efficiency (TE) criteria 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 2015, rotary screw traps (herein, "screw traps") were deployed upstream of reservoirs to capture juvenile salmonids as they moved downstream. The dates of trap deployment varied by basin with emergence timing of Chinook salmon observed in previous sampling years. Traps were operated throughout the calendar year until removal in late November or early December in anticipation of high stream flows.

The majority of juvenile spring Chinook salmon entered WVP reservoirs as fry [2014 brood year (BY); < 60 mm FL] in early spring, soon after emergence. This suggests that prior to dam construction, fry would have continued dispersing downstream throughout the Willamette Basin, similar to fry emigration observed in unimpounded tributaries of the McKenzie River. Chinook salmon fry typically entered WVP reservoirs from February through June. However, emergence and subsequent run timing were earlier in 2015 (range: 3-4 weeks) than in previous years, likely due to higher stream temperatures and accelerated egg development.

The average fork length (FL) of fry entering most WVP reservoirs in the spring was 35 mm, consistent with previous years. However, in our first year of operating the MFW-HC trap there was a wide variation in fork lengths for subyearling Chinook salmon captured in the spring in comparison to other traps. The variation in fork length could be explained by the two distinct adult spawning areas above the trap site that were ~22 km apart ("Construction Site" and Paddys Valley), resulting in variation in emergence timing and stream rearing duration.

Fall parr and spring yearling Chinook salmon (2013 BY) entering reservoirs were relatively rare compared to fry at all locations. However, the Middle Fork and North Fork Middle Fork rivers (and to a lesser extent the North Santiam) had more fall parr and spring yearling migrants

than other river systems above reservoirs. We suspect that this is partly due to the amount of rearing habitat between spawning areas and our trap sites in these river systems. River flow levels, incubation temperatures, distance from spawning areas to reservoirs, and quality of upstream rearing habitats can all affect reservoir entry timing and size of juvenile Chinook salmon.

Previous data collected from trapping below dams indicated that very few Chinook salmon fry (< 60 mm FL) continue migration through the reservoirs in the spring. This was consistent with 2015 data, as we captured few fry in traps below dams. We captured more fry below Cougar Dam than in any previous sampling season, but it is unclear whether this was due to low reservoir elevation (i.e., smaller reservoir size) or juvenile production directly below the dam. In Foster Reservoir, as in the past, it appeared that some Chinook fry passed successfully through the reservoir soon after emergence. However, most juvenile spring Chinook salmon exited WVP reservoirs as subyearlings in late fall and early winter (October – December), in conjunction with reservoir drawdown and lowered pool elevation.

We operated the screw trap in the Breitenbush River above Detroit Reservoir for the first time since 2011. Although the trap was not operating from June 19 through the end of the year due to low flows followed by high flows and debris, we estimated that 55,951 (95% CI ± 10,457) subyearlings migrated past our screw trap prior to that period. A vast majority (96%) of the Chinook salmon we captured moved into Detroit Reservoir as fry from February through April.

The number of subyearlings moving past our trap into Cougar Reservoir in 2015 was estimated to be 219,755 (95% CI ± 42,166). Most (90%) subyearlings moved into Cougar Reservoir as fry from March through May. We also estimated the number of subyearlings surviving to below Cougar Dam at 38,940 (95% CI ± 25,293). Using the above- and below-dam estimates, we concluded ~ 17.7% (4.5-37.3%) of the 2014 BY Chinook salmon migrating past the screw trap upstream of Cougar Reservoir in 2015 survived to below Cougar Dam. The estimated proportion of survivors is very similar to our estimate of 17.5% (11.6 – 25.0%) from 2013 for the 2012 BY.

The South Santiam River above Foster Dam is currently the only reach above a WVP reservoir with winter steelhead production. We captured 817 juvenile *O. mykiss* in the screw trap in 2015, compared to 835 in 2014. Previously we have reported that the age and seasonal timing of juvenile *O. mykiss* movement into Foster Reservoir is highly variable among years. In 2015 age-2 smolts accounted for a higher proportion (20%) of the annual catch than previous years (<7%). Age-0 juveniles typically comprised the majority of our annual trap catch, but in 2015 all age classes (age-0, age-1, age-2) were caught in relatively equal proportions. Subyearling *O. mykiss* emerged and began moving downstream in late May, earlier than in previous years, with the peak in migration in June and July. The maximum size of age-0 *O. mykiss* was ~100-110 mm FL by the end of December.

We PIT-tagged a total of 1,440 juvenile *O. mykiss* (using various methods of capture) upstream of Foster Dam in 2015 and summarized detections of fish passing the dam. We tagged 807 *O. mykiss* from January through June, comprised of yearlings (64.9%) and age-2 fish (35.1%). There were 69 detections at Lebanon Dam of these fish during the same period with age-2 fish comprising a significantly greater proportion (84.1%) of the detections (Chi-square test; $P \leq 0.001$). From July through December (summer/fall), we tagged 308 subyearlings (48.7%), 296 yearlings (46.8%), and 29 age-2 fish (5.0%). Only 17 fish from the summer/fall tag group have been detected downstream thus far with no age-2 fish detected. Detections of subyearlings (35.3%) and yearlings (64.7%) from this group were not significantly different from the proportions tagged (Chi-square test; $P=0.303$).

We summarized PIT-tag detection data from Willamette Falls and the Columbia River trawl detection sites for steelhead we tagged in the South Santiam River from 2011-2015. We found that regardless of the age they were tagged, a majority (95%) of steelhead from the South Santiam River migrated to the ocean as age-2 smolts (n = 82 detections), although a small percentage also migrated at age-1 and age-3. In addition, regardless of age, tagging location or season, all steelhead smolt detections occurred at Willamette Falls or in the Columbia Estuary from March – June.

Introduction

Spring Chinook salmon *Oncorhynchus tshawytscha* and winter steelhead *O. mykiss* in their respective upper Willamette River Evolutionarily Significant Units (ESUs) are listed as threatened under the U. S. Endangered Species Act (NMFS 1999a; NMFS 1999b). As a result, the National Marine Fisheries Service (NMFS) must evaluate whether any action taken or funded by a federal agency is likely to jeopardize these 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, and Bureau of Reclamation, collectively known as the Action Agencies. The BiOp 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 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 discharge modifications are under consideration to improve downstream passage and survival of juvenile migrants. Improving downstream 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, Big Cliff, Foster, and Cougar dams. We also summarize data collected from traps below Lookout Point and Fall Creek dams 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 primarily progeny from adults that were trapped and hauled upstream of WVP dams. Exceptions may include production from resident rainbow trout, or from adfluvial Chinook salmon adults. 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-10-2-0008-0035, for outmigration monitoring from April 2015–March 2016. Included in this report are a summary and analysis of field activities implemented by ODFW on behalf of the USACE through December 31, 2015, to address requirements of RPA measures prescribed in the Willamette Project BiOp (NMFS 2008). Primary tasks included: 1) continue to develop and maintain monitoring infrastructure; 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 above WVP reservoirs in 2015 were located on the North Santiam and Breitenbush rivers upstream of Detroit Reservoir, the South Santiam River upstream of Foster Reservoir, the South Fork McKenzie River upstream of Cougar Reservoir, and the North Fork Middle Fork Willamette River upstream of Lookout Point Reservoir (Figure 2). All rotary screw traps above project reservoirs were 1.5 m in diameter, and trapping sites remained consistent with 2012 sampling locations (Table 1; Romer et al. 2013), with the exception of the North Fork Middle Fork Willamette (NFMF) trap upstream of Lookout Point Reservoir, which was moved from the Middle Fork Willamette site at the USFS "seed orchard" and placed in the NFMF, and the addition of a trap in the Middle Fork Willamette river upstream of Hills Creek Reservoir (MFW-HC). Deployment date for each trap varied by basin with expected emergence timing based on observations in previous sampling years (Monzyk et al. 2011; Romer et al. 2012, 2013, 2014, 2015). Traps were operated until removal in late November or December in anticipation of high stream flows, with the exception of the South Santiam River trap that remained in place throughout the calendar year.

The North Santiam trap was located on private property downstream of the Coopers Ridge Road Bridge and was ~5.8 km upstream of Detroit Reservoir (at full pool). The South Santiam trap was also located on private property near the town of Cascadia and was ~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 ~1 km upstream of Cougar Reservoir (at full pool). The North Fork Middle Fork Willamette trap was located upstream of the town of Westfir on USFS property ~4 km upstream of the confluence with the Middle Fork Willamette River which is ~10 km upstream of Lookout Point Reservoir (at full pool). The MFW-HC trap was located in the Middle Fork Willamette River < 1 km upstream of Hills Creek Reservoir (at full pool).

Below Project Traps- We continued trapping efforts in 2015 below Big Cliff, Foster and Cougar dams (Table 1). We also summarized migrant data received from USACE personnel operating a 2.4-m trap located ~260 m downstream of the base of Lookout Point Dam, and their trap below Fall Creek Dam (Figure 2). Generally, controlled discharge from the dams allowed us to operate traps nearly every day of the year, except for events such as extremely high dam discharge (e.g., from the Cougar Dam regulating outlet channel for periods in the winter of 2015), low flow (e.g., the Cougar Dam turbine tailrace trap farthest from shore in 2015) maintenance, safety upgrades, or when debris or substrate movement prevented the trap from spinning (e.g., the Cougar Dam turbine tailrace in 2013 and 2015).

At Cougar Dam, juvenile salmonids have two routes by which they can pass 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 ~100 m downstream of the base of the dam. Our traps were positioned in each channel, enabling 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; Figure 1). The two traps in the tailrace operate side by side (Figure 1) as a single unit. The tailrace unit operated 292 d and the RO operated 334 d (Figure 4) in 2015.

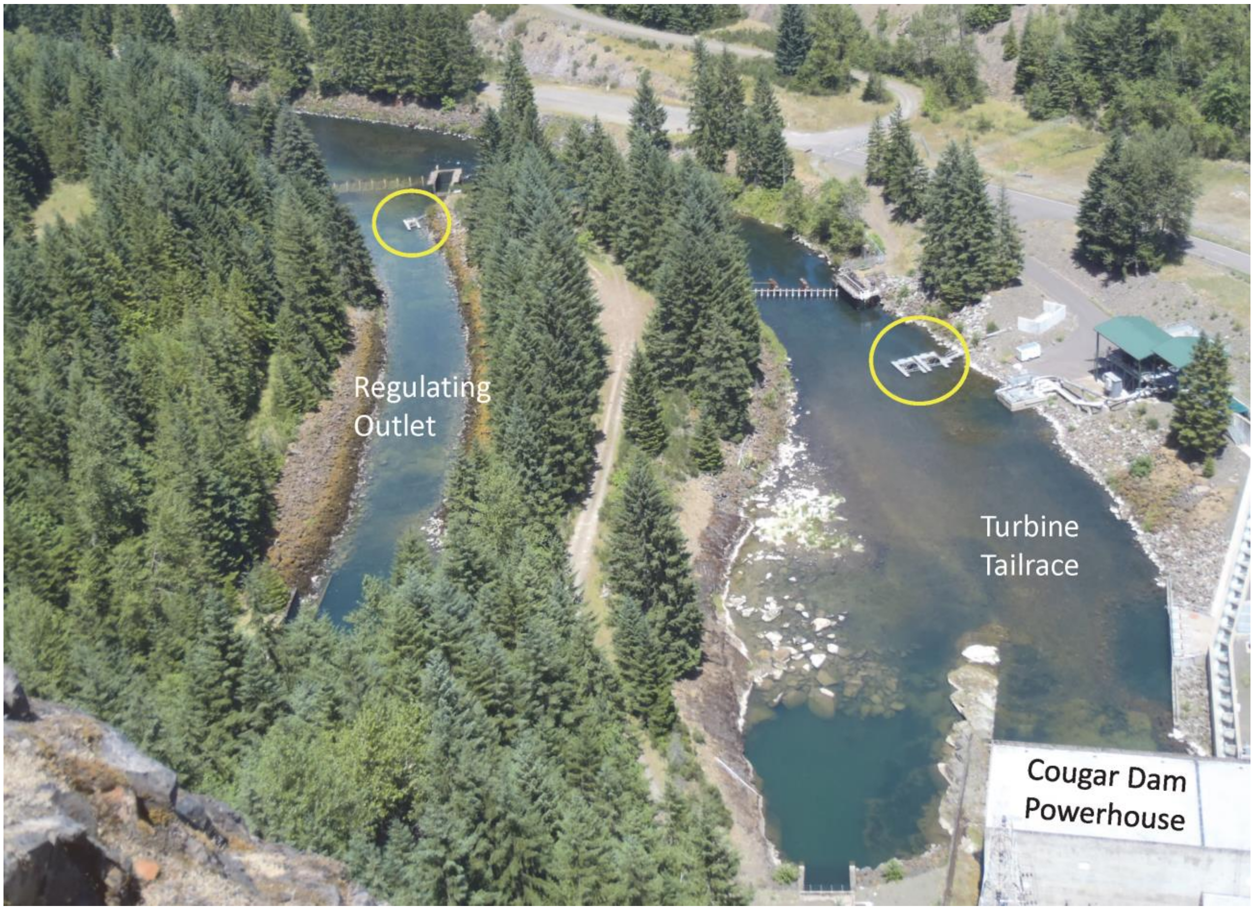

Figure 1. Rotary screw traps below Cougar Dam (1.5-m diameter in regulating outlet, 2.4-m diameter x 2 in tailrace; South Fork McKenzie River rkm 385).

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. Additionally, the large trap size and the tailrace hydraulic conditions resulted in several periods of low trap rotations (≤ 2 rpm) that likely resulted in low capture efficiency. Due to limited trapping information collected for salmonids at this site in previous years (for the reasons stated above) the Willamette BiOp Research Monitoring and Evaluation (RM&E) Team suggested removal of this trap in 2016. The trap was removed on April 19, 2016.

Table 1. Installation dates and location of rotary screw traps above and below Willamette Valley Project reservoirs, 2015. 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	January 27	286	0568785 4955753
North Santiam	February 19	292	0575240 4949260
South Santiam	January 1	271	0539897 4915479
South Fork McKenzie	February 18	395	0562654 4877522
North Fork Middle Fork Willamette	February 25	364	0541029 4846205
Middle Fork Willamette (upstream Hills Cr. Reservoir)	March 6	384	0543872 4827972
Below Dams			
Big Cliff	January 1	266	0554987 4956117
Foster	January 4	253	0526128 4917989
Cougar Tailrace	January 1	379	0560486 4886873
Cougar RO	January 5	379	0560486 4886873
Lookout Point	January 14	333	0519724 4862480
Fall Creek	January 5	314	0519233 4865845

Juvenile Salmonid Outmigration Timing and Size

Traps above reservoirs were operated continuously throughout the year, unless flows (high or low) prohibited effective fishing (Figure 3). Effective operation of traps below dams depended on discharge from dam outlets (Figure 4). All traps were checked and cleared of fish and debris daily when weather conditions permitted, with more frequent visits during storm events or periods of high debris transport. The fish numbers we report here for trapping reflects actual catch and were not adjusted for trap efficiency (TE) or days when the trap was not operated, unless otherwise stated. In addition to collecting migrant information on spring Chinook salmon, the South Santiam trap (above Foster Dam) was located downstream of most major spawning habitat for adult winter steelhead, which also facilitated collection of migration data for juvenile steelhead.

Fish captured in traps were removed, identified to species, anesthetized with MS-222, measured, and counted. Age class of Chinook salmon (subyearling or yearling) was estimated in the field based on relative size differences between cohorts. We measured FL to the nearest mm from all fish classified as “yearlings” and a subsample of “subyearlings” (minimum of 50 per day) and released all fish ~100 m downstream of the trapping site, except for those retained for TE estimates. Age estimates that were determined in the field using relative size differences in fish were subject to some small, unknown level of error.

Age estimates of measured juvenile Chinook salmon were quality checked with length-frequency analysis (DeVries and Frie 1996). Juvenile Chinook salmon had a bimodal size distribution with minimal overlap of age classes throughout the year, allowing for delineation of yearlings and subyearlings. We plotted individual fish size by date at each trap and determined juvenile age. Juveniles that hatched in spring 2015 (2014 BY) were classified as subyearlings, and yearlings were fish that hatched the previous year (2013 BY) and remained in the reservoir after January 1, 2015. Salmonids < 60 mm were considered fry. We report outmigration timing during the calendar year (January 1 – December 31, 2015). Therefore, yearlings and subyearlings comprise different cohorts.

In the South Santiam River, 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 presumed that most of the juvenile *O. mykiss* captured in our trap were the progeny of adult steelhead due to the large number of adult steelhead transported upstream of Foster Reservoir. The number of *O. mykiss* caught in the South Santiam trap upstream of Foster Reservoir is usually an order of magnitude greater than in other basins where steelhead are not present.

Juvenile Chinook salmon and winter steelhead > 65 mm FL were tagged with passive integrated transponder (PIT) tags (Prentice et al. 1990; Appendix A; Table A1; A2; A4) to collect recapture and detection information (Appendix A; Table A3; A5) regarding growth and migration behavior. Growth information can be found in Monzyk et al. (2014, 2015a). We tagged additional *O. mykiss* in the South Santiam River above Foster Reservoir to gather information on dam passage timing. We collected fish in the reservoir with Oneida nets and in the mainstem South Santiam River and in upstream tributaries (Moose and Canyon creeks) with seines and hook and line sampling.

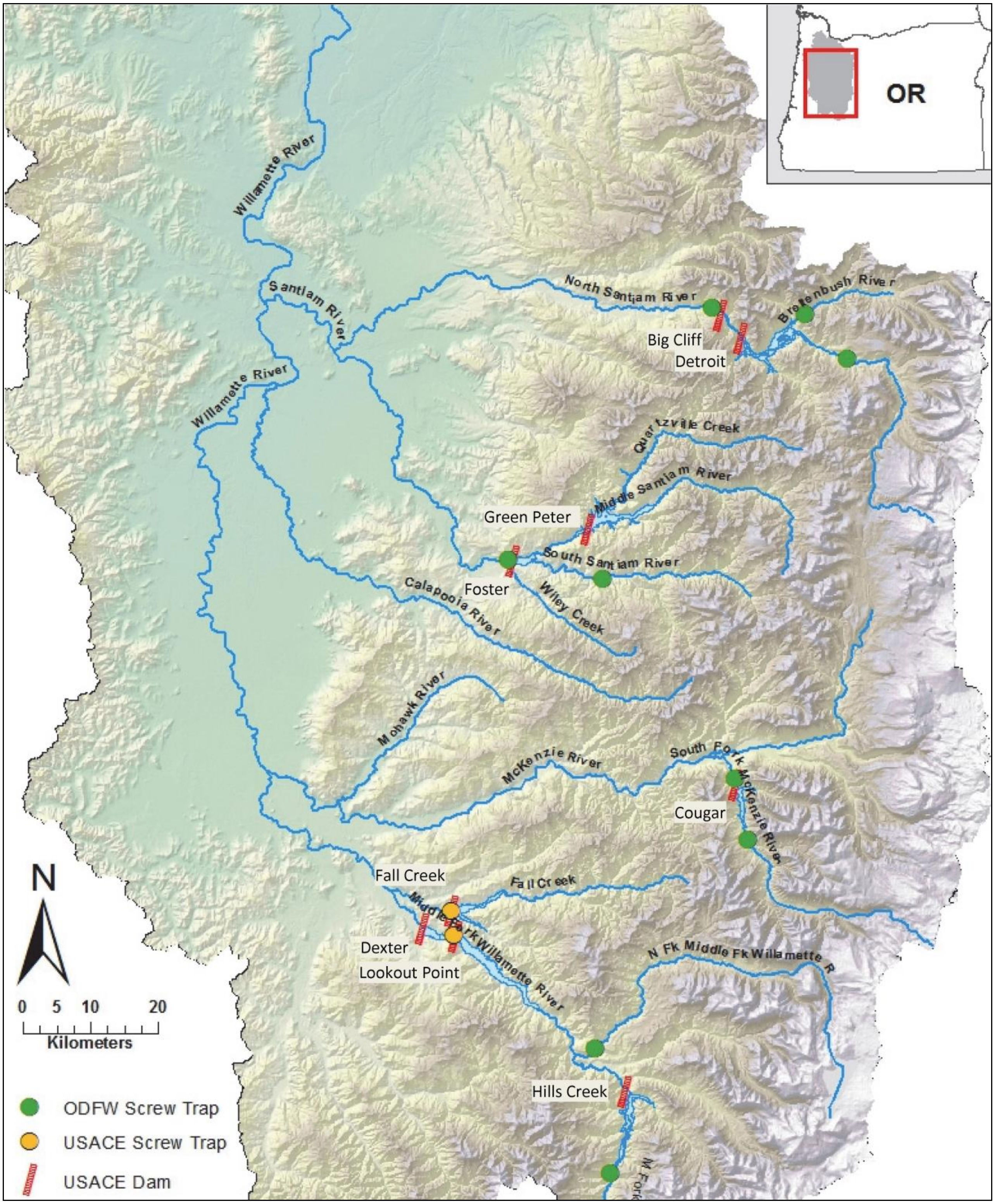

Figure 2. Locations of rotary screw traps operated by the Oregon Department of Fish and Wildlife (ODFW) and USACE above and below Willamette Valley Project dams.

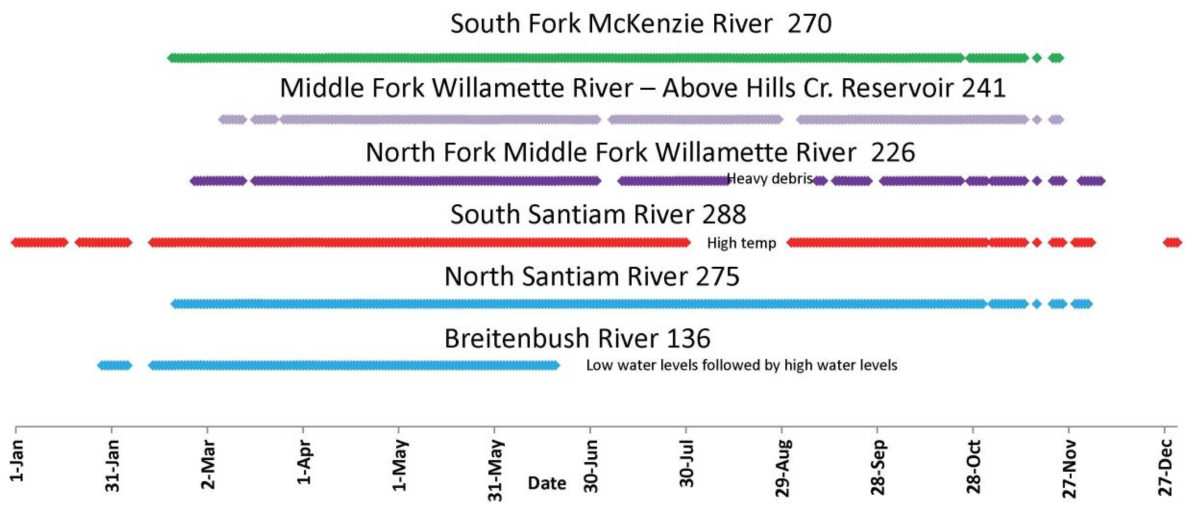

Figure 3. Screw trap operation summary for traps upstream of Willamette Valley reservoirs, 2015. Each colored dot represents one day of operation; numbers are the number of days the trap operated during the calendar year.

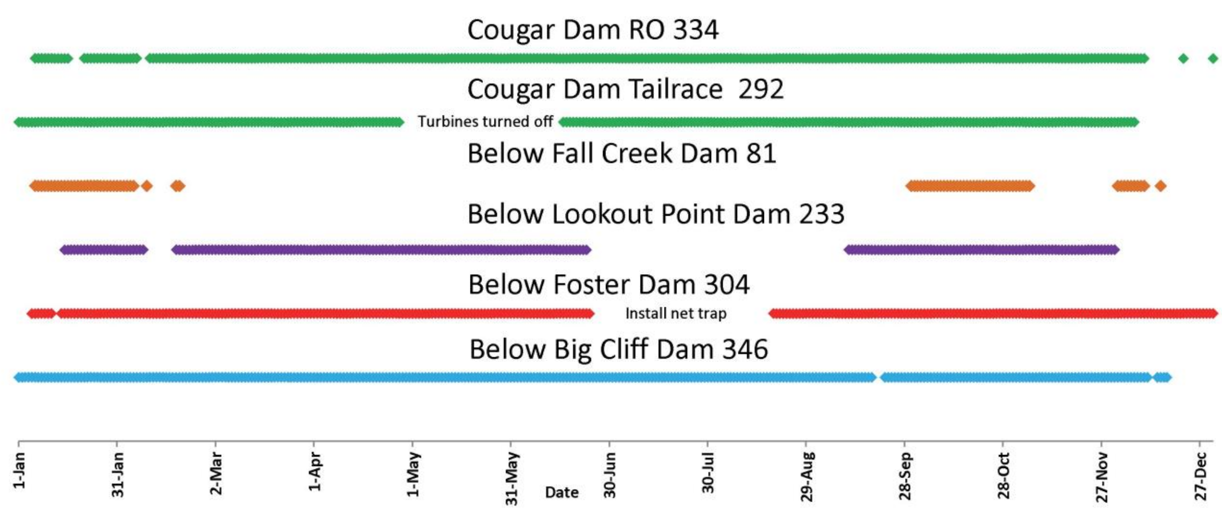

Figure 4. Screw trap operation summary for traps below dams in the upper Willamette River Basin, 2015. Each colored dot represents one day of operation; numbers are the number of days the trap operated during the calendar year. Tailrace = turbine tailrace. RO = regulating outlet.

Abundance Estimates of Outmigrating Chinook Salmon

We calculated trap capture efficiency weekly for each species (Chinook salmon or *O. mykiss* in the South Santiam) and age class (based on fork length) by marking fish from each species and age-class category with PIT-tags or a small clip from the caudal fin and releasing them upstream ~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 cumulative catch data for the year (between 25th and 75th percentiles). 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 yearly 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 fish captured was reported. Migrant abundance for periods when traps were stopped due to high flows or debris were estimated using the mean 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 the yearly migrant total estimated to have passed the trap that week, 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 (< 60 mm FL) were the predominant migrants caught in screw traps above reservoirs, with peak migration occurring in the spring but varying as much as two months among sub-basins. Small proportions of juveniles were collected between mid-June and December at most of the upstream trap sites, suggesting that most juvenile Chinook salmon migrate into WVP reservoirs in the early spring. The exceptions to this pattern were in the NFMF, where there appeared to be a large pulse of subyearlings leaving in the fall (September – December) and MFW-HC, where subyearlings trickled out throughout the year following the initial, much larger pulse in the spring. This was the first year we operated the NFMF trap and it is unclear if the fall pulse is typical at this site.

The greatest catch of Chinook salmon in traps below Project dams occurred primarily during late fall and early winter during reservoir drawdown and were comprised mainly of subyearlings. There were two exceptions to this pattern. At Foster Dam most Chinook Salmon were typically captured from January to April. Below Lookout Point Dam no subyearling Chinook salmon were collected.

North Santiam River- We operated the screw trap in the North Santiam River above Detroit Reservoir from February 19 until December 3, 2015. The trap fished for 275 d and captured 1,646 subyearling Chinook salmon and 42 yearlings. The run timing and size of Chinook salmon fry captured in the North Santiam trap were similar to subyearlings observed in the South Fork McKenzie River. The peak migration was in April (Figure 5) with a median migration date of April 20. This was the earliest median migration date observed for subyearlings at this trap (Appendix B; Table B2). Most subyearlings (82% of our catch) entered Detroit Reservoir during March - May as fry averaging 36 mm FL (Figure 6). Debris load in the trap started increasing in October and the trap was stopped and restarted several times in November due to high flows and debris. Similar to 2010 (2009 BY), 2013 (2012 BY) and 2014 (2013 BY), we observed a smaller pulse of subyearling movement during this period which was not observed in 2011 and 2012 (2010 - 2011 BY; Figure 5). The size range for subyearlings caught throughout the season was 28-131 mm FL.

The number of subyearlings captured appeared to be related to the number of adult females transported upstream of the reservoir the previous year. For comparison, in 2011 (2010 BY) and 2013 (2012 BY) we captured 4,255 and 311 subyearlings, respectively, in the North Santiam screw trap. The number of females transported upstream of Detroit Reservoir was 746 in 2010 and 98 in 2012 (Appendix B; Table B1).

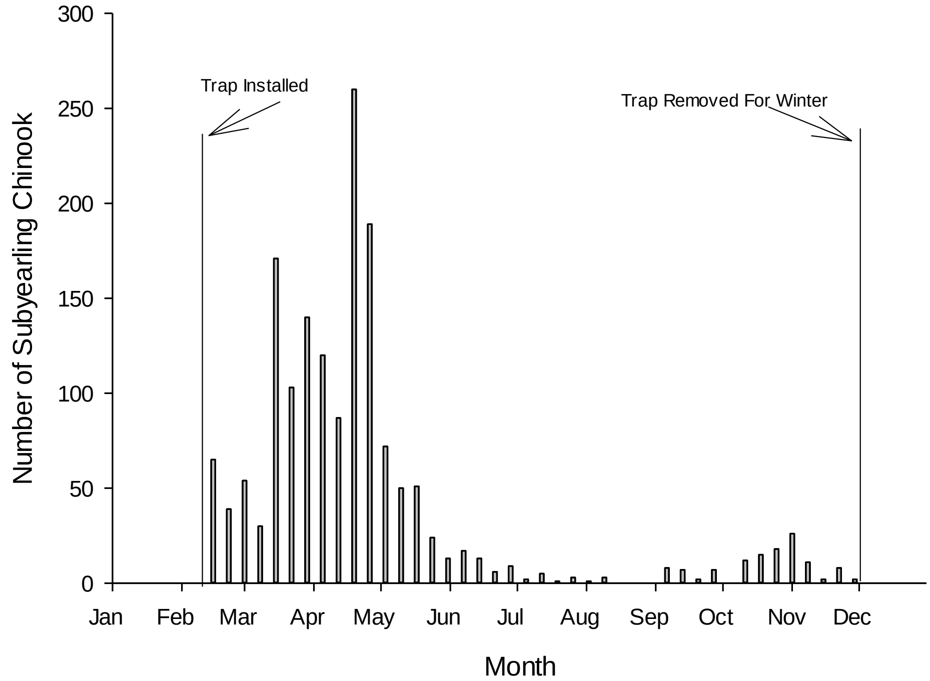

Figure 5. Weekly catch of subyearling spring Chinook salmon captured in the North Santiam trap above Detroit Reservoir, 2015.

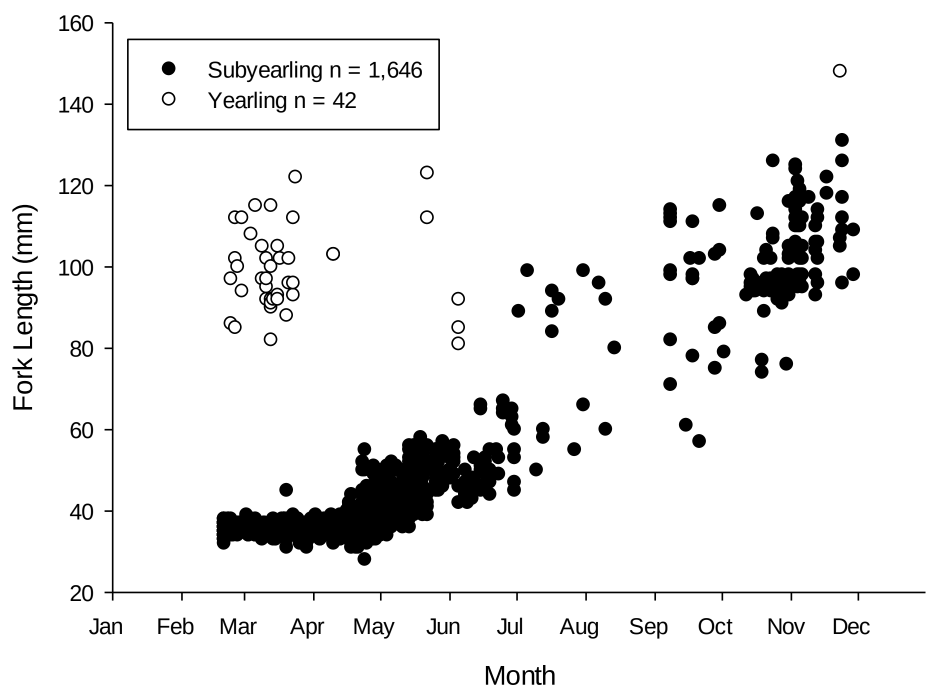

Figure 6. Fork lengths of juvenile Chinook salmon captured in the North Santiam trap above Detroit Reservoir, 2015.

Breitenbush River- We operated the screw trap in the Breitenbush River above Detroit Reservoir for the first time since 2011. The trap operated for 136 d from January 27 until June 19, and captured 2,620 subyearling Chinook salmon (Figure 6). The peak of migration was in March - April (Figure 7) with a median migration date of March 27 (Appendix B; Table B2). Similar to 2011, migration timing (i.e., fry emergence) in the Breitenbush River was earlier than the North Santiam River. Most subyearlings (88% of our catch) entered Detroit Reservoir during March - May as fry averaging 35 mm FL (Figure 8). The trap was stopped on June 19 due to low flows that would not spin the trap. Low flow conditions remained through October, followed by high flows and debris that lasted until we removed the trap on November 18. Even though the trap did not run the entire year we were able to estimate the number of subyearlings entering Detroit Reservoir (*Abundance estimates of outmigrants* section of this report).

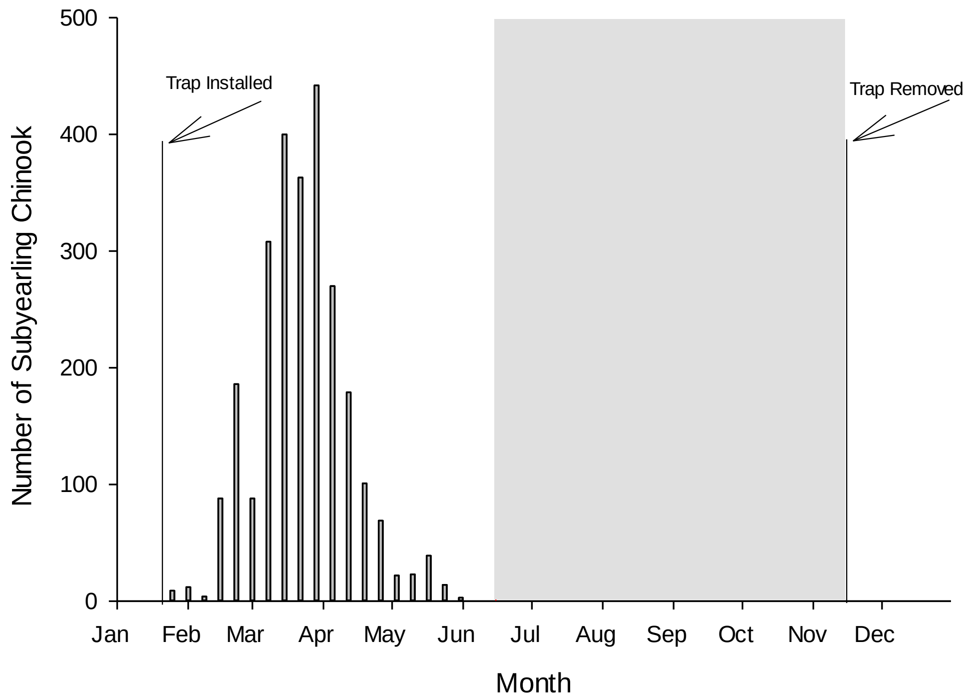

Figure 7. Weekly catch of subyearling spring Chinook salmon captured in the Breitenbush River trap above Detroit Reservoir, 2015. Shading indicates the period the trap was not operated due to low or high flows.

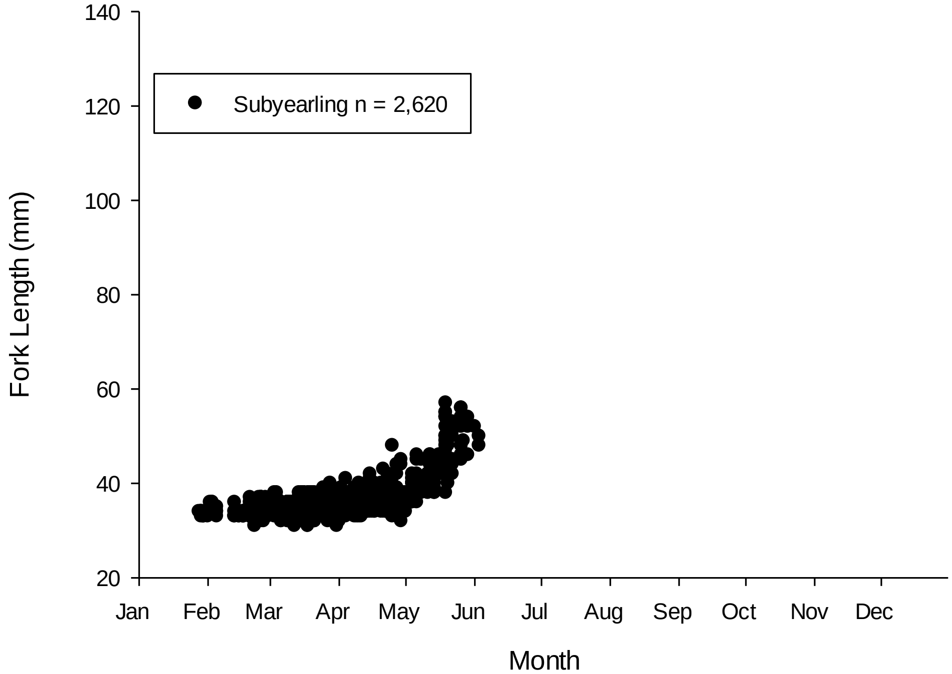

Figure 8. Fork lengths of juvenile Chinook salmon captured in the Breitenbush trap above Detroit Reservoir, 2015.

Below Big Cliff Dam- We continued operation our 1.5-m diameter trap below Big Cliff Dam, which provided downstream passage information for the combined Detroit/Big Cliff projects. The trap below Big Cliff Dam operated 346 d in 2015. The peak in passage of juvenile Chinook salmon exiting Big Cliff Dam occurred in November - December (Figure 9). Overall, the outmigration pattern for Chinook salmon appeared similar to previous years when trapping was conducted directly below Detroit Dam.

The trap below Big Cliff Dam captured 141 unmarked Chinook salmon, 156 hatchery Chinook salmon, and 149 kokanee. Many of the hatchery Chinook salmon captured below Big Cliff in 2015 originated from the release of ~66,000 PIT-tagged fish into Detroit Reservoir (all released at the head of Detroit Reservoir due to high surface temps in the forebay) on August 6, 2015 (mean FL 81 mm; Brandt et al. 2016). Of the recaptured hatchery Chinook salmon from this release group between August 28 and December 31, most (99%) were collected in November during the peak in dam passage timing.

Gas bubble disease has been an issue for fish caught in the screw trap below Big Cliff Dam. In April and May 2014 we observed high fish mortality (92% for Chinook salmon) in our trap, much higher than at other traps below dams. Several fish captured in the trap (both live and dead) in 2014 had gas bubbles in their fins, suggesting gas bubble disease. Supersaturation of dissolved gases was highly correlated with increased spill over Big Cliff Dam (Spearman rank order correlation coefficient 0.84; $P < 0.001$) and was discussed at length in Romer et al. (2015). We did not observe similar high mortality in 2015 as spill discharge did not occur in spring 2015 and only five Chinook salmon were captured below Big Cliff Dam from March – June. Spill over Big Cliff Dam did not begin until December 5 in 2015 and from April 1 to December 5, only 16% of the salmonids examined exhibited signs of gas bubble disease (n=280). After December 5, all salmonids examined in the trap exhibited signs of gas bubble disease (n=40). Dam discharge, reservoir elevation and corresponding catch for all species below dams for 2015 are summarized by month in Appendix D to provide context for fish trapping data.

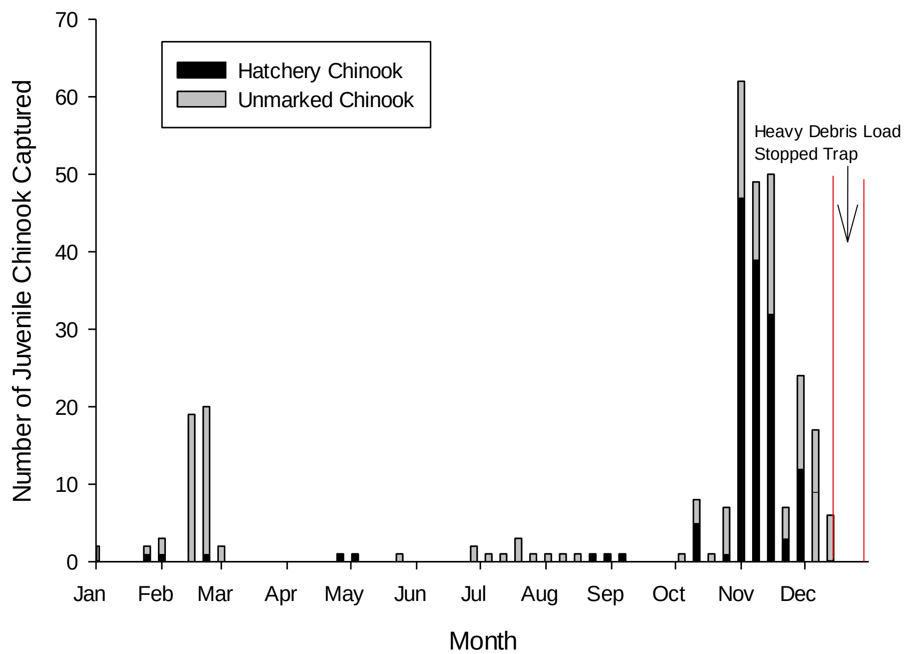

Figure 9. Weekly catch of marked and unmarked Chinook salmon (subyearling and yearlings) captured in the rotary screw trap below Big Cliff dam, 2015.

South Santiam River Spring Chinook Salmon - We operated the South Santiam trap upstream of Foster Reservoir from January 1 through December 31, 2015. The trap did not operate from July 30 - August 30 because of high water temperatures and from December 4 – 27 due to high flows (Figure 10). The trap fished for 288 d in 2015 and captured 52 subyearlings and five yearlings.

Chinook salmon in the South Santiam River emerged earlier than other sub-basins. The first fry from the 2015 BY were captured December 30, 2015, soon after restarting the trap after a high flow event (Figure 11). Similarly, the first fry from the 2014 BY were captured on December 18, 2014 (n = 12). Subyearlings captured in the screw trap upstream of Foster Reservoir were larger in May and June than their stream-rearing counterparts in other sub-basins, likely due to their earlier emergence timing (Figure 22; Romer et al. 2015).

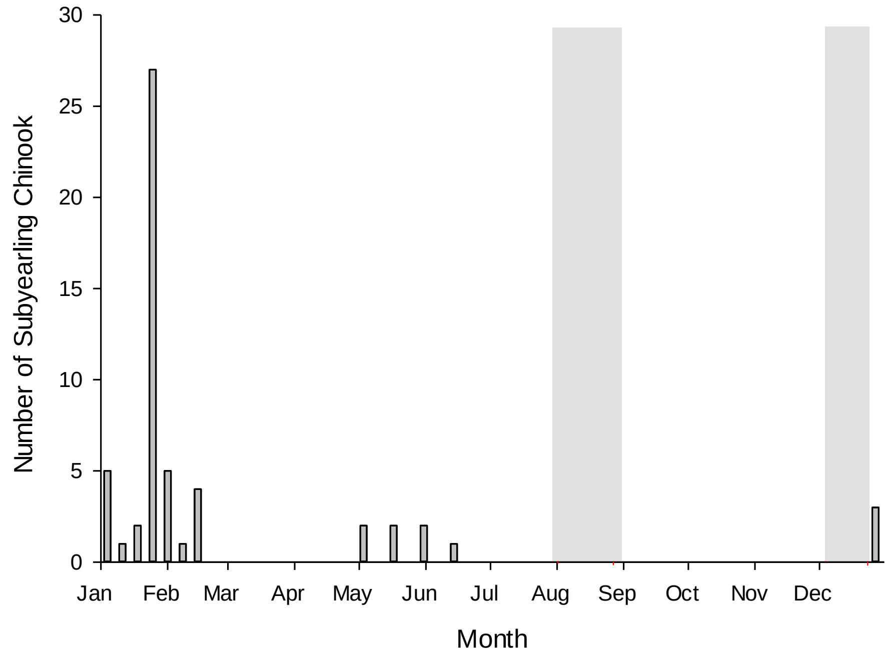

Figure 10. Weekly catch of subyearling spring Chinook salmon captured in the South Santiam trap above Foster Reservoir, 2015. Shaded areas indicate periods when trap was stopped due to either low flows (August) or high flows (December).

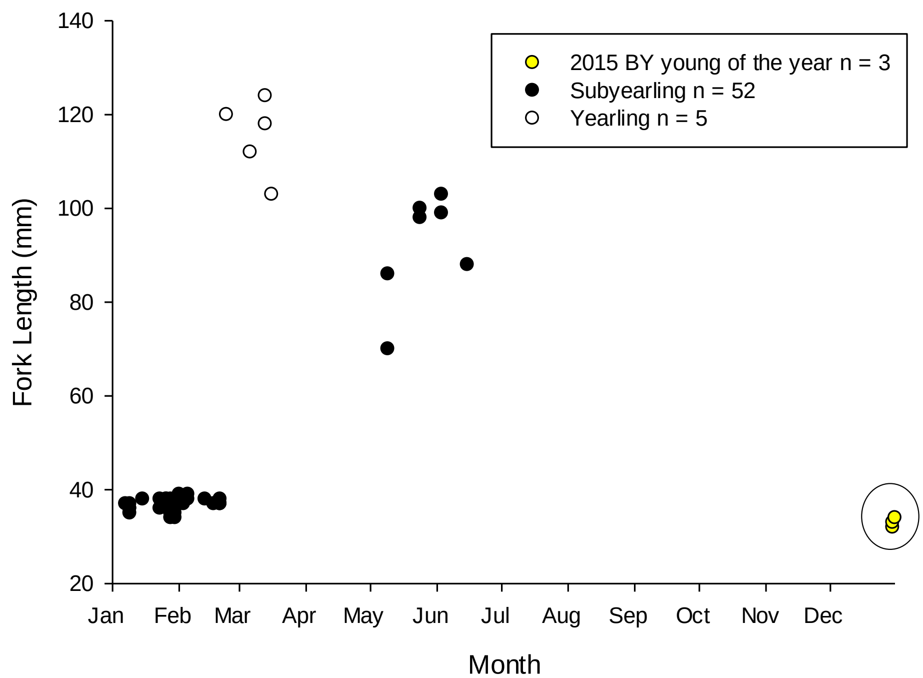

Figure 11. Fork length of subyearling and yearling Chinook salmon collected in the South Santiam trap above Foster Reservoir, 2015.

We discussed in previous reports that we suspected high, scouring flows in the South Santiam River during critical stages of egg incubation may limit juvenile production in some years, specifically the 2010 BY (Romer et al. 2013; Romer et al. 2015). A high flow event on January 16, 2011 peaked at 26,900 cfs, a level not reached since 1999. Only 15 fish from the 2010 BY were captured in the screw trap after the flood event (14 subyearlings, one yearling) and we suspected a near-complete year-class failure. This was supported by O'Malley et al. (2015) who concluded that the 2010 BY made minimal contributions to the adults returning to the South Santiam River in 2013 (age 3) and 2014 (age 4) based on genetic parentage analysis, suggestive of a brood year failure in 2010. Although adults returning in 2015 as age 5, and 2016 as age 6 from the 2010 BY have yet to be summarized, most adult Chinook salmon typically return to the South Santiam River at age 4 (Sharpe et al. 2015). The pedigree analysis showed that very few of the age-4 adults (2010 BY) returning to Foster dam were produced above Foster Reservoir. It should be noted that in previous reports, we stated the January 2011 high flow event at 11,800 cfs based on provisional USGS data at gauging station 14158000 near Cascadia. Peak flow data for the site has since been estimated at 26,900 cfs.

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 presumed that most of the juvenile *O. mykiss* captured in our trap were the progeny of adult steelhead due to the large number of adult steelhead transported upstream of Foster Reservoir. The number of *O. mykiss* caught in the South Santiam trap upstream of Foster Reservoir is usually an order of magnitude greater than in other basins where steelhead are not present. In addition, suspected resident fish (>350 mm FL) were not included in the following analyses even though they were PIT-tagged.

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 (Busby et al. 1996). In the South Santiam River, juvenile *O. mykiss* migrate into Foster Reservoir at age-0, age-1, or age-2 and rear for a variable amount of time before exiting the reservoir. In the spring, only age-1 and age-2 fish are present in the basin. The first age-0 juveniles typically begin entering the reservoir in late June soon after emergence, and this age-class continues to enter the reservoir through the rest of the year (Romer et al. 2015). Juveniles can exit Foster Reservoir at any of the three age-classes, although age-2 smolts are the primary age class that continues to the Columbia River estuary (discussed later in this report).

The 817 juvenile *O. mykiss* captured in the South Santiam screw trap in 2015 was typical of most years at this site with annual catch ranging from 502 - 1,405 fish (Table 2). Juveniles were comprised of at least three age groups based on length-frequency distributions (DeVries and Frie 1996; Figure 12). Most age-2 smolts and age-1 juveniles were caught in May and most age-0 juveniles were caught in June as newly emergent fry (Figure 13). Although a second pulse of juveniles (age-0 and age-1) were caught in late fall, it was minor compared to catch in the spring. The proportion of our annual catch comprised of age-1 and age-2 fish in the spring was atypically high compared to previous years (Figures 13 and 14).

Table 2. Catch of juvenile *O. mykiss* and days of trap operation at the South Santiam screw trap, 2010-2015.

Year	Days of operation	Total catch
2010	175[a]	1,187
2011	223[b]	502
2012	269	1,405
2013	327	865
2014	291	835
2015	288	817

[a] Trap not started until 10 May, 2010.
[b] High and low river flows frequently precluded trap operation.

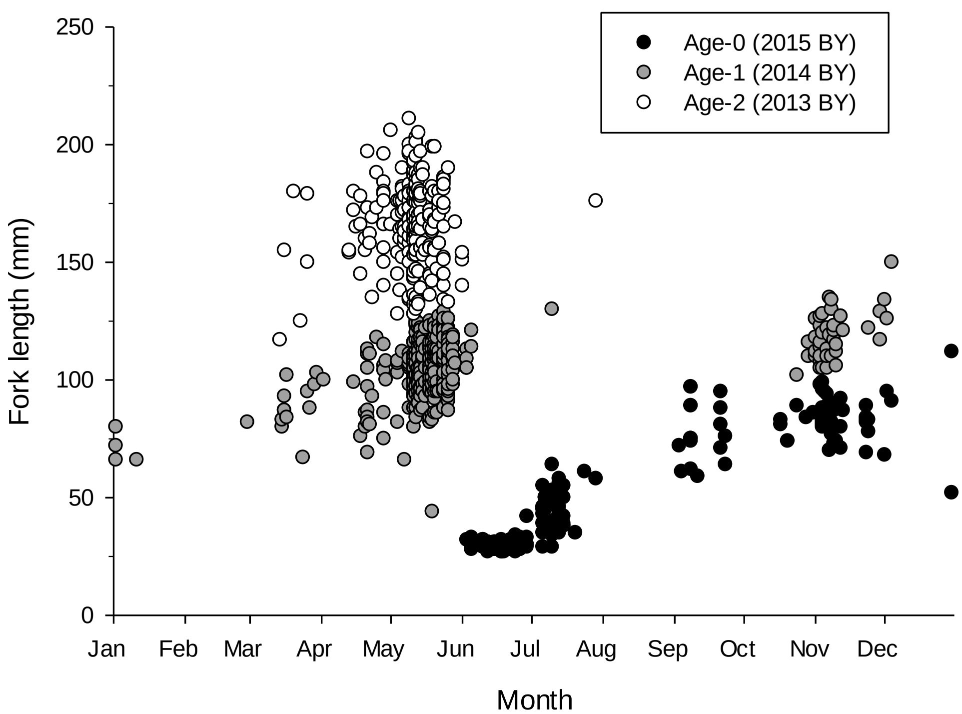

Figure 12. Fork lengths and estimated age of *O. mykiss* caught in the South Santiam trap above Foster Reservoir, 2015. Age estimated from length-frequency analysis. BY = brood year.

Juvenile *O. mykiss* from of the upper South Santiam have shown considerable interannual variability in the age and timing of reservoir entry. Catch of age-2 smolts in the spring has been variable among years. In 2015 age-2 smolts accounted for 20% of the total catch for this brood year (2013 BY) whereas in previous years, age-2 smolts accounted for <7% of the brood year catch (Table 3). Age-0 juveniles typically comprise the majority of our annual trap catch, but in 2015 all age classes were caught in relatively equal numbers (Figures 12 and 13). This was the result of unusually larger catches of age-1 and age-2 juveniles in the spring and fewer than usual age-0 juveniles caught in late summer and fall (Figure 12 and 13). Another example of variability in reservoir entry timing was in 2014 when age-0 and age-1 trap catch was punctuated by a large pulse of fish over a few days in late October with few fish collected before or after this period (Figure 14). We hypothesized that the extremely low river flows in 2014 may have hindered juvenile *O. mykiss* outmigration from tributary rearing areas until the first freshets at the end of October. The high catch in the spring of 2015 of age-1 and age-2 fish may be an artifact of the limited outmigration of age-0 and age-1 fish the previous fall.

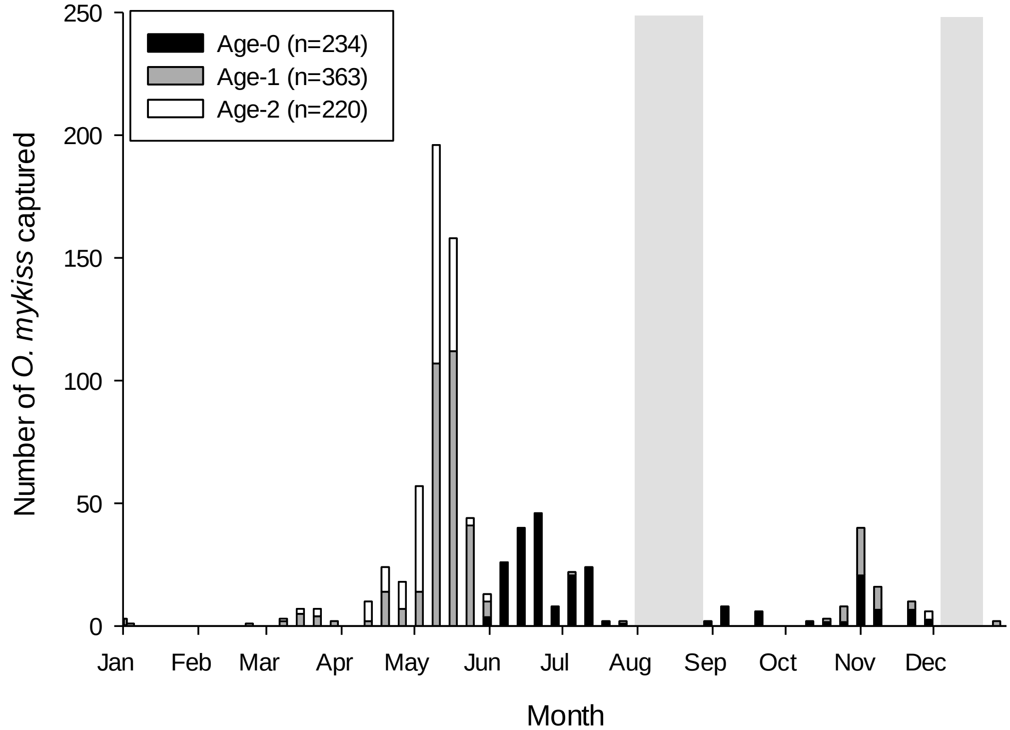

Figure 13. Weekly catch and estimated age of juvenile *O. mykiss* captured in the South Santiam trap above Foster Reservoir, 2015. Shaded areas indicate periods when trap was stopped due to either low flows (August) or high flows (December).

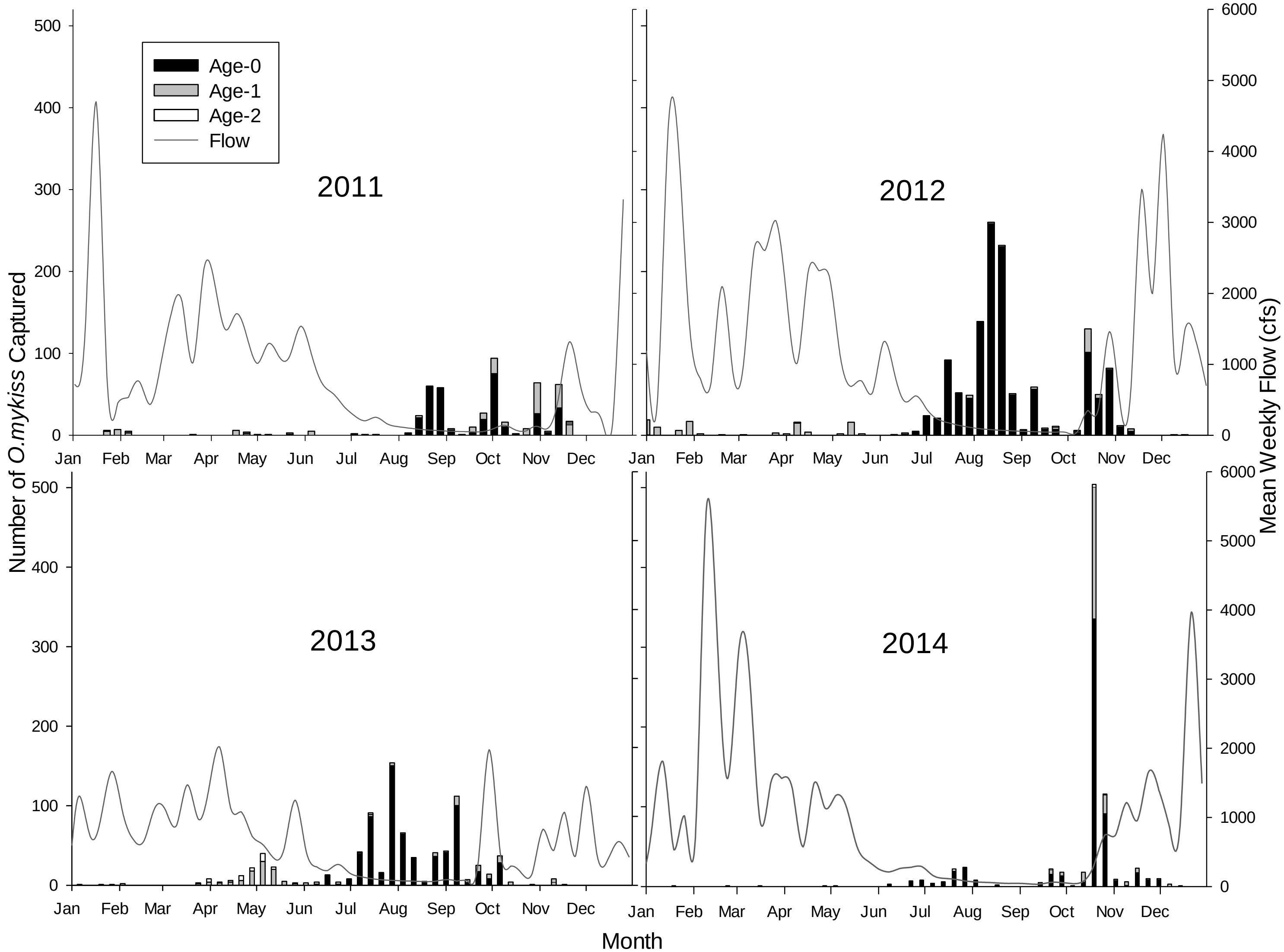

Figure 14. Number of *O. mykiss* captured in the South Santiam trap and mean weekly flow (ft^3/s) summarized by week for trapping seasons 2011-2014.

Table 3. Proportion of juvenile *O. mykiss* collected in the South Santiam River screw trap upstream of Foster Reservoir by age for brood years 2010-2013. Numbers in parentheses are the total number of juveniles from a brood year collected in the trap over the three years juveniles were expected to pass the trap site.

Age	2010 BY (n=1,165)	2011 BY (n=553)	2012 BY (n=1,413)	2013 BY (n=1,107)
0	0.87	0.66	0.88	0.60
1	0.13	0.28	0.12	0.20
2	<0.01	0.06	<0.01	0.20

South Santiam River Winter Steelhead PIT-tag detection Information - The main objective of PIT-tagging juvenile *O. mykiss* in the South Santiam River above Foster Reservoir was to determine dam passage timing. Tagged fish had the possibility for detection at either the Foster Dam weir or an antenna array on Lebanon Dam. Travel time between Foster and Lebanon dams averaged 2.4 d (n=8), so we made the assumption that a detection at Lebanon Dam was representative of Foster Dam passage timing. We report detections of tagged fish through January 20, 2016, but given that some fish could still migrate out of Foster Reservoir in spring 2016, detection histories reported here should be considered incomplete. We tagged 1,440 juvenile *O. mykiss* in 2015 upstream of Foster Dam, comprised of 22% age-0, 56% age-1, and 22% age-2 fish (Table 4). Most (n=621) were collected from the screw trap on the mainstem South Santiam River, primarily in the spring.

Table 4. Location, estimated age, and number of juvenile steelhead PIT tagged upstream of Foster Dam in the upper South Santiam basin, 2015. *O.mykiss* captured upstream of the dam that were suspected resident fish (>350 mm FL) were not included in this table (2 Canyon Cr.).

Tagging Location	Age-0	Age-1	Age-2	Total
Canyon Creek	226	136	20	382
Moose Creek	1	77	2	80
Mainstem South Santiam River[a]	52	363	218	633
Foster Reservoir	29	244	72	345
Total	308	820	312	1,440

[a] Included catch from the screw trap and hook-and-line sampling.

We tagged 807 juvenile steelhead from January through June 2015, comprised of age-1 (65.2%) and age-2 fish (34.8%). Sixty-nine of these fish were detected at downstream sites during the same period with age-2 fish comprising a significantly greater proportion (84.1%) of the detections (Chi-square test; $P \leq 0.001$). The ratio of age-2 to age-1 exiting Foster Reservoir, adjusted for different tagging proportions, was nearly 10:1.

During summer and fall (July-December), we tagged 308 age-0 (48.7%), 296 age-1 (46.8%), and 29 age-2 fish (4.5%). Only 17 fish from the summer/fall tag group have been detected downstream thus far, all during November-December. No age-2 fish were detected. Detections of age-0 fish (35.3%) and age-1 fish (64.7%) were not significantly different from the proportions tagged (Chi-square test; $P=0.303$) although sample sizes were small resulting in low power (0.165). The ratio of age 1 to age 0 detected exiting Foster Reservoir, adjusted for tagging proportions was 1.9:1. Two age-1 fish tagged in the spring were also detected in the fall. Overall, fewer fish were detected exiting in the fall compared to the spring but antenna detection efficiencies were likely lower in the fall due to higher river discharge and periods of antenna malfunction. A more complete description of dam passage timing by age class for fish tagged in 2015 can be made after spring 2016.

Our screw trapping and preliminary PIT-tag detection information showed that juvenile steelhead in the South Santiam River enter and exit Foster Reservoir at all ages. However, the majority of fish that enter the reservoir are age-0 fish while age-2 fish appear to comprise the majority of fish exiting the reservoir, suggesting that the reservoir serves as rearing habitat for a large portion of the juvenile population. Whether we would observe a similar pattern of reservoir entry for juvenile steelhead above Detroit Reservoir is currently unknown. The North Santiam and Breitenbush rivers above Detroit Reservoir contain more juvenile rearing habitat than the South Santiam River (R2 Resource Consultants 2007) which may result in fish rearing in streams for a longer period and entering the reservoir primarily as age-2 fish. Our screw traps upstream of Detroit Reservoir will help confirm this hypothesis after steelhead are released above the dam.

An additional objective of our *O. mykiss* PIT-tagging efforts is to determine age and timing of South Santiam steelhead smolts entering the Columbia River and migrating to the Pacific Ocean. We started tagging *O. mykiss* in our screw trap in 2011, added tagging in Foster Reservoir in 2013, and then added tagging in tributaries (Moose and Canyon creeks) in 2014-2015. The number of *O. mykiss* tagged each year can be found in Appendix A; Table A4. In the following paragraph, we summarize information from detection arrays at Willamette Falls and NOAA's Columbia River Trawl from 2011-2015.

We found that regardless of the age they were tagged, a majority (95%) of *O. mykiss* from the South Santiam River migrated to the ocean as age-2 smolts (n = 82 detections; Table 5), although a small percentage also migrated at age-1 and age-3. In addition, all *O. mykiss* smolt detections occurred at Willamette Falls or in the Columbia River Estuary from March – June (Figure 15).

Table 5. The age at tagging and age at detection (Willamette Falls or Columbia River Estuary) for South Santiam River steelhead, 2011-2015.

			Age at Tagging (Age Detected)				
Year Tagged	Number Tagged	Number Detected	0	1	2	3	% Smolt Detections Migrating at Age-2
2011	205	2		2	(2)		100
2012	370	1		1	(1)		100
2013	800	18	2	2	14 (18)		100
2014	1,802	36	3	32 (3)	1 (32)	(1)	89
2015	1,468	25			25 (25)		100

We also used data from *O. mykiss* tagged in 2014-2015 upstream of Foster Dam which were subsequently detected at both Foster Weir and Willamette Falls (known migrants; n = 12) to estimate the average travel time between Foster Dam and Willamette Falls. The size range of *O.*

mykiss detected at both sites was 138-199 mm at the time of tagging. Interestingly, once the smolts began their downstream migration (indicated by detection at the Foster Weir) it took only an average of 6 d (range 4-9 d) to make the 211-rkm journey to Willamette Falls. This converts to an average downstream movement of 1.5 rkm/h. All fish detected at both sites (Foster and Willamette Falls) migrated in spring 2015 (two were tagged in 2014), so the estimated travel time is specific to 2015 smolts but is likely variable among years and dependent on environmental conditions. In addition, regardless of age, tagging location or season, all *O. mykiss* smolt detections occurred at Willamette Falls or in the Columbia Estuary from March – June.

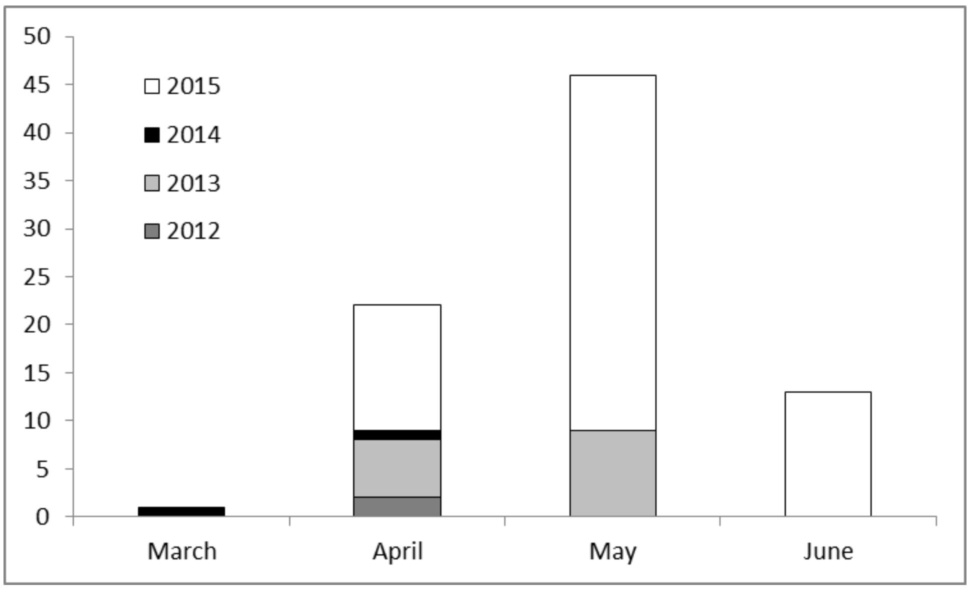

Figure 15. Steelhead smolt detections by month (N=82) at Willamette Falls or the Columbia Estuary during seaward migration. Year corresponds to the year of migration (or detection), not to year tagged.

Below Foster Dam - The 2.4-m screw trap below Foster Dam operated from January 4 – December 31, 2015 and ran for 305 d. The trap did not operate from June 24 – August 17. Dam discharge, reservoir elevation and corresponding catch for all species summarized by month are presented in Appendix D; Table D2 and Figure D2.

We captured 35 unmarked subyearling Chinook salmon (2014 BY) and five yearlings throughout the year (including 10 fry from November – December, 2014). The migration timing and size of subyearling Chinook salmon collected below Foster Dam suggested that some subyearling Chinook salmon moved through Foster Reservoir into downstream rearing areas when the reservoir was at lower pool elevation (Figure 16, Appendix D; Figure D2). Our screw trap was positioned just downstream of the turbine outflow and was unable to sample fish exiting via the spillway. As noted above, ten fry from the 2014 brood year were captured below Foster Dam in late November and December, 2014. This emergence timing is earlier than previous observations (Romer et al. 2015), and it is likely that these fry were a result of spawning that occurred below the dam. The first fish from the same brood year weren't captured upstream of Foster Reservoir until December 18, 2014.

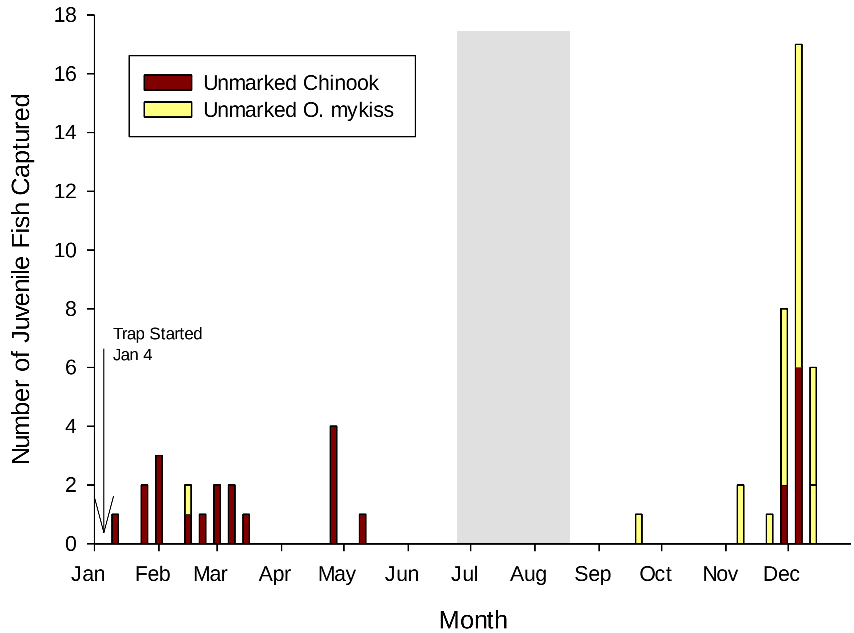

Figure 16. Weekly catch of unmarked Chinook salmon and *O. mykiss* captured below Foster Dam, 2015. Shaded area indicates period when trap was stopped.

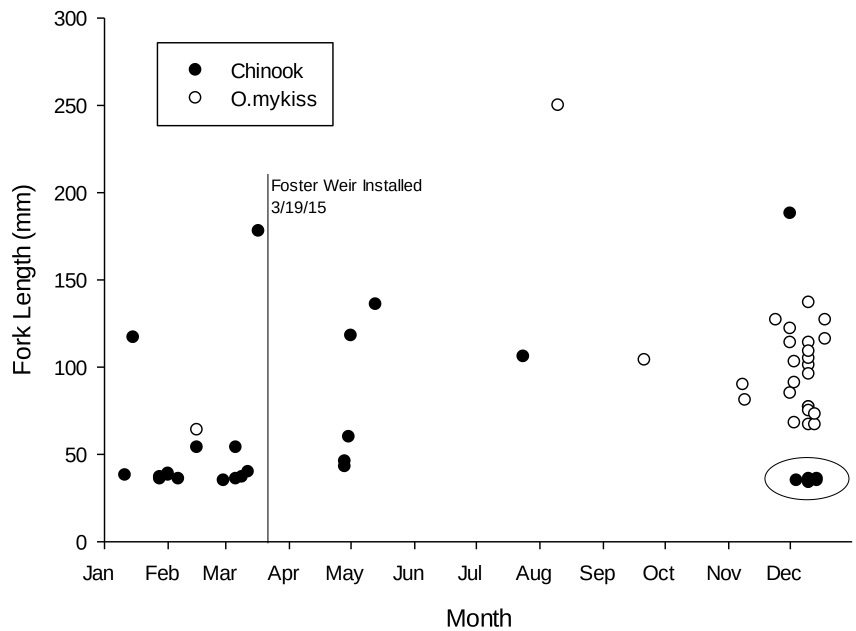

Figure 17. Fork lengths of unmarked juvenile spring Chinook salmon and *O. mykiss* captured in the rotary screw trap below Foster Dam, 2015. The black vertical line represents the installation of the PIT-tag antenna in Foster Dam fish weir. Oval indicates 2015 BY Chinook salmon fry.

We also captured 27 *O. mykiss* below Foster Dam, compared to 195 in 2014 (38 in 2013, 141 in 2012). Fish ranged in size from 64-250 mm FL and were likely comprised of three age-classes (ages 0-2). We were unable to reliably assign age from length-frequency analysis because of the overlap in sizes (Figure 16). The overlap was probably due to differences in fish growth rates between the two rearing habitats (stream and reservoir) and the variable length of time individuals reared in the reservoir. We have documented that age-0 *O. mykiss* entering Foster Reservoir from the South Santiam River reach a maximum size ~100 – 110 mm FL by the end of December (Romer et. al 2014), so the *O. mykiss* < 100 mm FL captured below Foster from October-December (n=14) were almost certainly age-0.

Middle Fork Willamette River (upstream of Hills Cr. Reservoir) - We operated the MFW-HC trap from March 6 through November 24, 2015. The trap fished for 241 d and captured 377 Chinook salmon subyearlings and 66 yearlings. The peak of the fry migration was March - May (Figure 18), and the median migration date was March 29 (Appendix B; Table B2). The trap started catching fry as soon as the trap was deployed. We likely missed the first portion of the fry migration in this sub-basin.

Subyearling size varied more in spring (Figure 19) compared to other sub-basins, suggesting some newly emergent fry rear in the stream for a period before moving downstream. Spatial variability in stream temperatures and emergence timing in the two distinct spawning areas of the Middle Fork Willamette River may contribute to the variation in subyearling size observed at our trap. Adult are transported above Hills Creek Reservoir to the 'Construction Site' located 15.7 km upstream of our trap and Paddys Valley located 21.9 km farther upstream. The river section between these release sites has deep pools conducive for rearing and this may explain the increased variation in fork lengths observed in Figure 19 in comparison to other trapping sites, and the increased proportion of yearlings captured the spring (due to better overwinter rearing habitat).

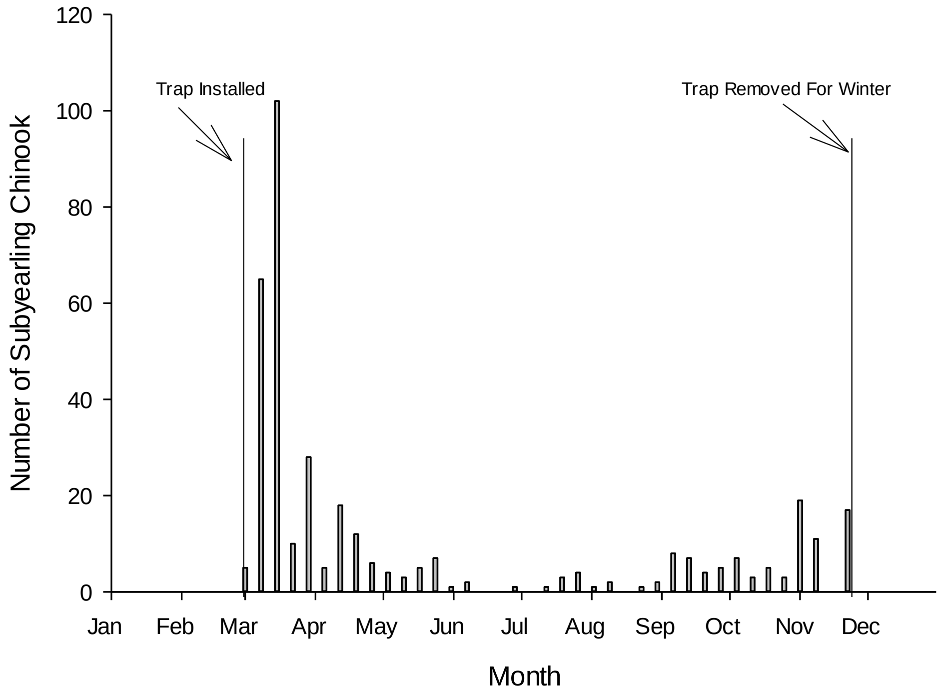

Figure 18. Weekly catch of subyearling spring Chinook salmon captured in the Middle Fork Willamette trap above Hills Creek Reservoir, 2015.

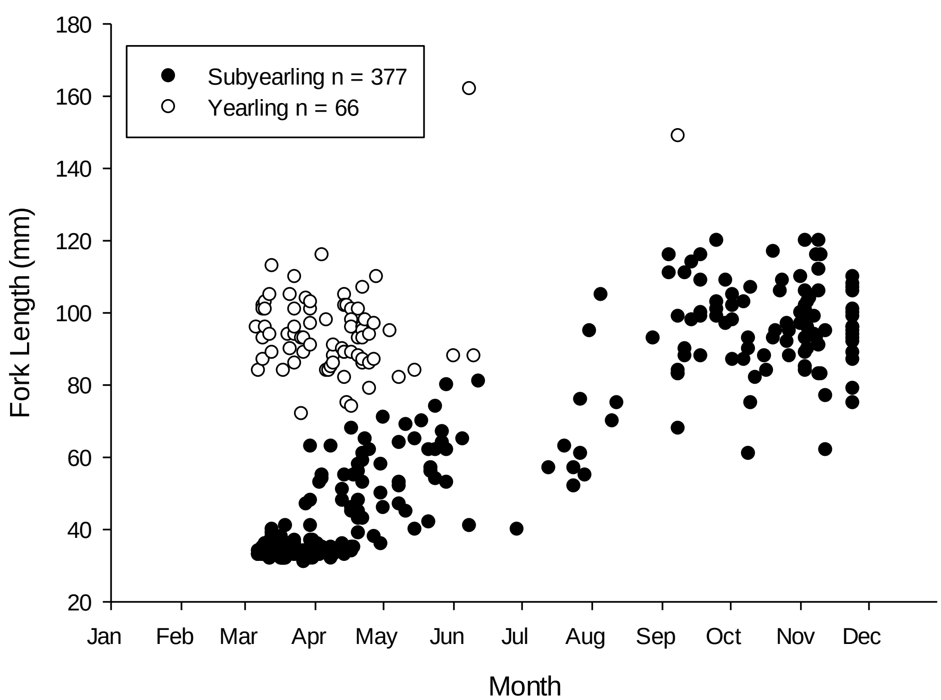

Figure 19. Fork lengths of juvenile Chinook salmon captured in the Middle Fork Willamette River trap above Hills Creek Reservoir, 2015.

North Fork Middle Fork Willamette River- We operated the North Fork Middle Fork (NFMF) Willamette River trap upstream of Lookout Point Reservoir from February 25 through December 7, 2015. This was the first year we operated a trap at this site. The trap fished for 226 d and captured 230 Chinook salmon subyearlings and 78 yearlings (Figure 21). We also captured a 208-mm fork length brook trout on June 15, presumably an emigrant from Waldo Lake in the headwaters of the NFMF Willamette River. The peak of the Chinook salmon fry migration was March - May (Figure 20). The median migration date for all subyearlings was May 16 (Appendix B; Table B2). Although most subyearlings (57% of total subyearling catch) migrated into the reservoir in the spring, a large proportion (42%) of subyearlings migrated into Lookout Point Reservoir from September - December with the greatest weekly catch occurring in early December (Figure 20). Compared to other traps, the NFMF trap also caught a larger number of yearlings in the spring that overwintered in the river. In 2006, USACE operated a trap in the same location on the NFMF for a short period from November - December and captured several subyearlings (USACE *unpublished data*). In most other Willamette River sub-basins, > 90% of Chinook salmon migrate into reservoirs as fry.

Subyearling Chinook salmon entering reservoirs (Lookout Point in particular) later in the fall and winter may have a higher probability of survival to below the dam than those migrating into the reservoir early in the spring as fry for several reasons: 1) higher flow from the river during this period combined with lower reservoir elevations and increased discharge from the dam could provide guidance flow through the reservoir reducing reservoir residence time; 2) fall migrants (and yearlings) would be larger and better at avoiding predators 3) temperatures would be lower than during mid-summer (avoid thermal stress and predators would be less active) 4) increased turbidity resulting from higher flow could decrease the ability of predators to locate these fish at the head of the reservoir.

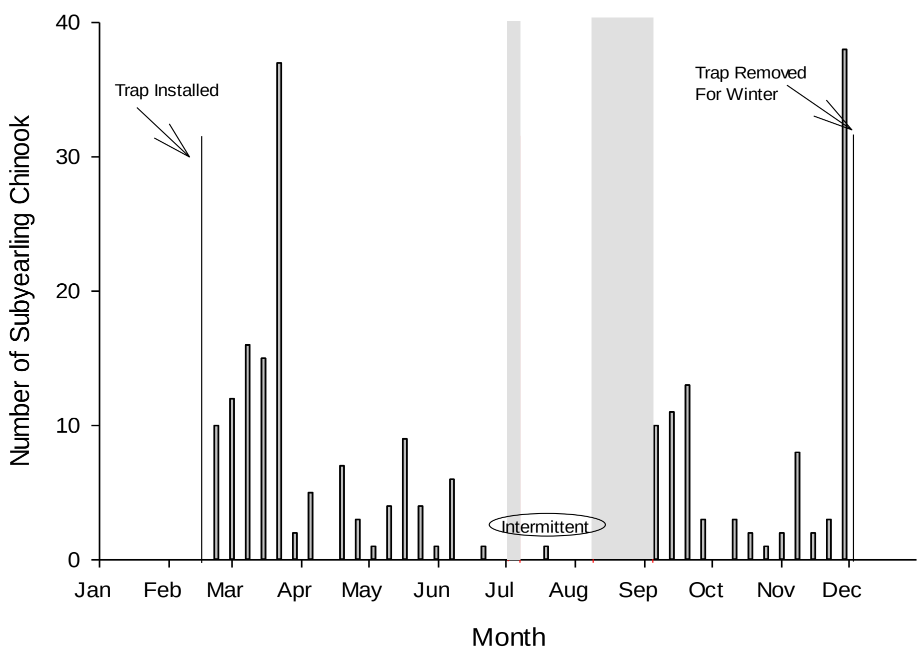

Figure 20. Weekly catch of subyearling spring Chinook salmon captured in the North Fork Middle Fork Willamette trap above Lookout Point Reservoir, 2015. Shaded areas indicate periods when trap was stopped due to low flow (July) or heavy debris loads (August).

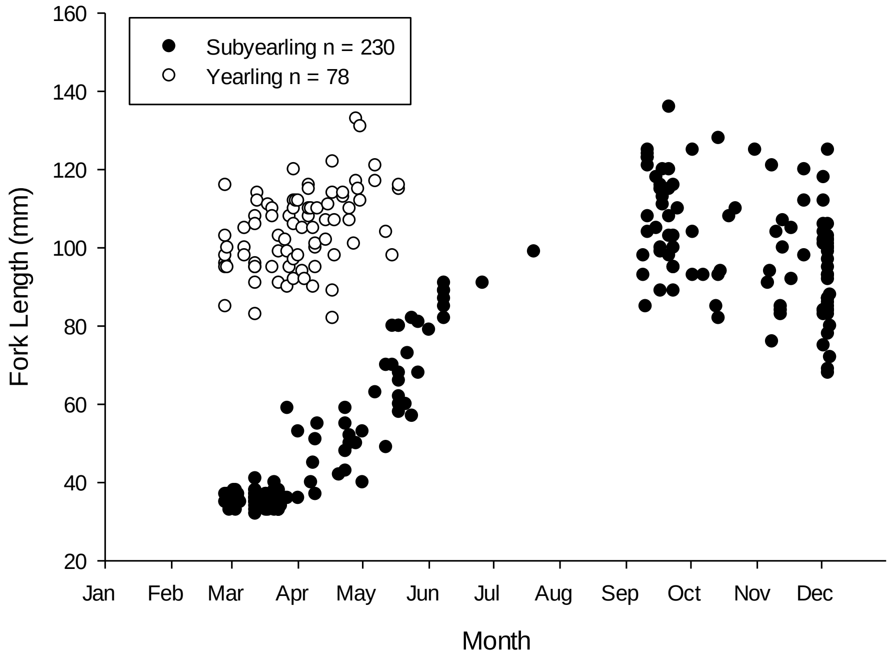

Figure 21. Fork lengths of juvenile Chinook salmon captured in the North Fork Middle Fork Willamette River trap above Lookout Point Reservoir, 2015.

The MFW-HC and the NFMF traps captured a larger proportion of yearlings in late winter and spring (February-May) than the other traps located upstream of reservoirs. In 2015, yearlings (n = 78) comprised 25.3% of the total catch in the NFMF. Both traps are located farther from spawning areas (39 and 54 km, respectively) than traps in other sub-basins and these rivers are larger in general than other sub-basins, offering deep pools conducive for juvenile holding and rearing which are rare in other sub-basins where we sample.

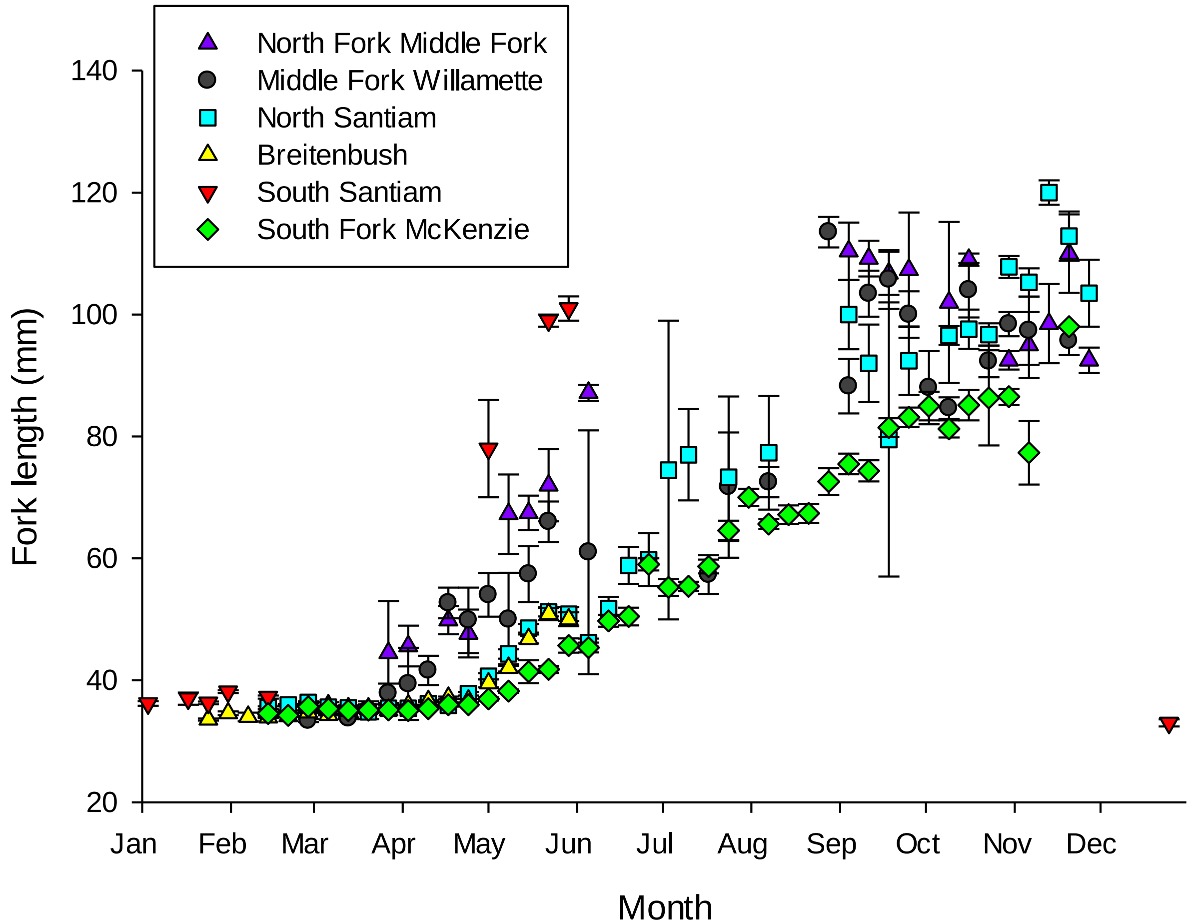

Figure 22. Fork lengths of subyearling spring Chinook salmon at each upstream screw trap location, 2015. Data were summarized by week and error bars represent the standard error. The screw trap on the Middle Fork Willamette River was upstream of Hills Creek Reservoir.

Below Lookout Point Dam- Personnel from USACE operated a 2.4-m screw trap below Lookout Point Dam from January 14 to December 1, 2015. The trap operated for 233 d but did not operate from June 23 - September 9 due to malfunction and delayed repairs. The trap captured one hatchery and ten unmarked yearling Chinook salmon (no subyearlings were captured) throughout the season. There were no releases of PIT-tagged Chinook salmon into Lookout Point Reservoir in 2015, the last year of the ODFW paired release study in Lookout Point Reservoir was 2014 (Brandt et al. 2016). Dam discharge, reservoir elevation and corresponding catch for all species, summarized by month, are provided in Appendix D; Table D3 and Figure D3.

Below Fall Creek Dam- Historically, the USACE lowered the reservoir pool level to a minimum of 728 feet above sea level during the winter drawdown. This meant that juvenile fish had to sound at least 50 feet to reach the regulating outlets to exit the reservoir. In 2011 USACE started lowering the reservoir to 680 feet above sea level annually ('deep drawdown') to facilitate downstream juvenile Chinook salmon emigration from the reservoir.

Personnel from USACE operated a 2.4-m screw trap below Fall Creek Dam from January 5 to December 15, 2015. The trap operated 81 d but did not operate from February 19 – September 28 because dam discharge was too low to spin the trap. Discharge was increased at the end of September and the trap operated intermittently until November 5 when the trap was pulled through December 1 for reservoir drawdown. Following the completion of reservoir drawdown, the trap was restarted on December 1 and fished until the 15th. The trap captured 130 unmarked subyearling Chinook salmon (n = 127 in November). No yearling Chinook salmon were captured, as would be expected following the deep drawdown. Dam discharge, reservoir elevation and corresponding catch for all species, summarized by month, are provided in Appendix D; Table D4 and Figure D4.

South Fork McKenzie River- We operated the South Fork McKenzie River trap upstream of Cougar Reservoir from February 18 to November 24, 2015 and fished for 270 d. The first fry were captured on February 19 (n=10), immediately after the trap was installed, suggesting that we may have missed a small portion of the first emergent fry in the system. The peak fry capture occurred from March - May (Figure 23), with a median subyearling migration date of April 9 (Appendix B; Table B2). This was the earliest subyearling median migration date that we have observed for this trap (2010-2014 range: April 26 – May 16). Warm stream temperatures during egg incubation likely accelerated fry emergence in 2015 (Appendix El; Figure E1). Although fry emergence in 2015 was earlier than usual, the predominance of subyearlings during early spring in our total trap catch was consistent with findings from previous work (Bureau of Commercial Fisheries 1960; Monzyk et al. 2011; Zymonas et al. 2011; Romer et al. 2012, 2013, 2014, 2015). Overall, we collected 4,996 Chinook salmon subyearlings and 19 yearlings (Figure 24).

The size of subyearling Chinook salmon ranged from 30-136 mm FL, and the mean fork length from March through May was 36 mm (n = 2,103, range 30-52 mm FL), approximately the size at which most would be expected to enter the reservoir. Very few yearlings were captured (n=19).

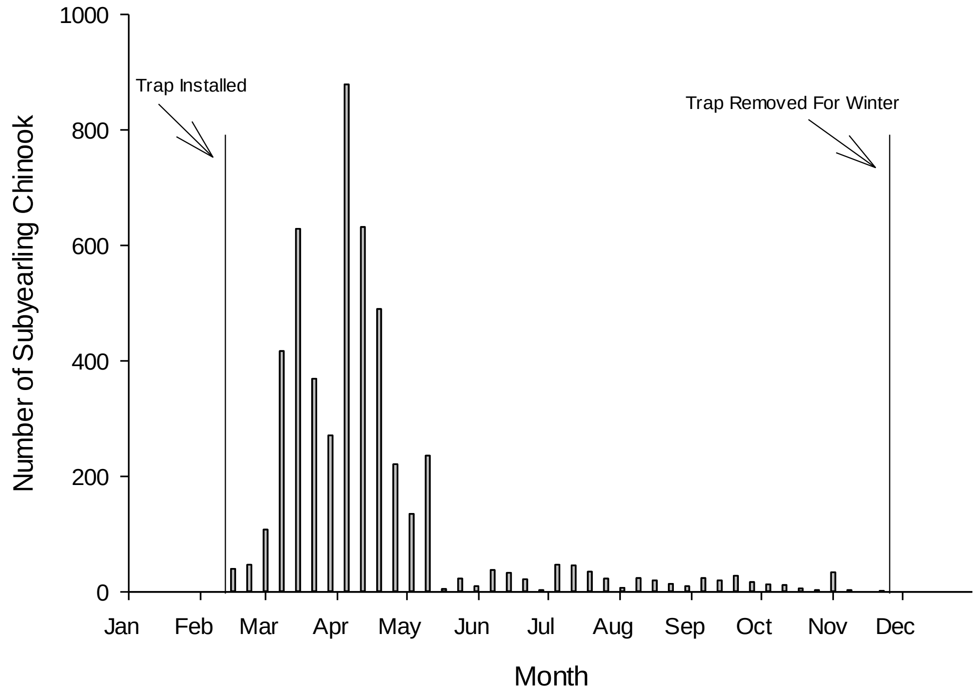

Figure 23. Weekly catch of subyearling spring Chinook salmon captured in the South Fork McKenzie River trap above Cougar Reservoir, 2015.

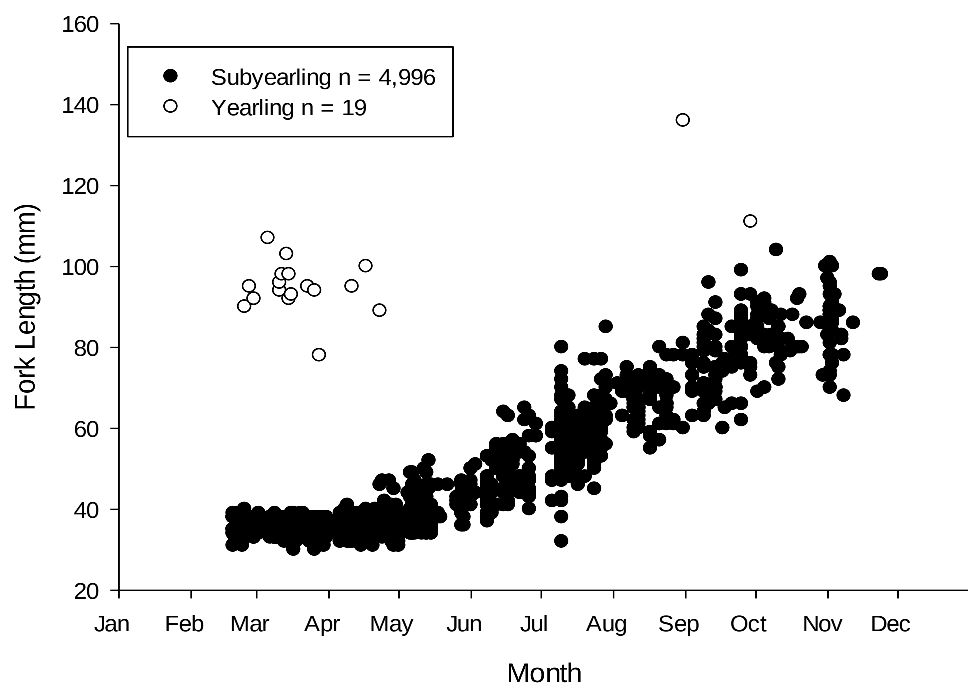

Figure 24. Fork length of subyearling and yearling Chinook salmon collected in the South Fork McKenzie River trap above Cougar Reservoir, 2015.

Below Cougar Dam – We operated only two of our three rotary screw traps below Cougar Dam for most of the 2015 field season. On February 20, the trap farthest from shore in the Cougar tailrace did not operate because the trapping site was too shallow for the cone to spin and it did not operate for the rest of the year. Neither tailrace trap was operating from April 27 – June 14 because the turbines were turned off and there was no flow in the tailrace channel. The total trap catch from all traps below the dam included 1,256 subyearling and 61 yearling unmarked Chinook salmon (Figure 26).

Subyearling catch included 336 fry (< 60 mm FL) in both the RO and tailrace traps (13 in the RO; 323 in tailrace). Capture of the first fry below Cougar Dam (January 21) was earlier than observed in previous years, and the number of fry captured was also greater than in previous sampling seasons (Appendix C; Figure C1). One possible explanation for the increased fry catch below the dam was the early fry emergence in the South Fork McKenzie upstream of the dam and smaller size of Cougar Reservoir (lower pool elevation) than in previous years due to drought conditions in 2015, allowing fry to more easily navigate the length of the reservoir. This hypothesis is supported by the large fry catch in the Portable Floating Fish Collector (located in the Cougar Reservoir forebay) in March, the first month of its operation in 2015 (Todd Pierce USACE –pers. Comm.). Alternatively, fry catch below Cougar Dam could be the result of natural production just below the dam in the substrate between the turbine outflow and our trap tailrace traps. Genetic samples were collected from the fry to determine origin but have not been analyzed to date.

Most (60%) subyearlings passed the dam in November and December, coinciding with lower reservoir pool elevations and increased discharge, primarily from the regulating outlet (Figure 25 and 26, Appendix D; Figure D5) consistent with last year (Romer et al. 2015). Dam discharge, reservoir elevation and corresponding catch for all species summarized by month are provided in Appendix D; Table D5 and Figure D5.

Consistent with previous years (except 2013), 2015 yearling dam passage timing occurred primarily in the spring even though there was very little discharge from the RO while the reservoir was refilling. We only captured 61 yearlings the entire season below Cougar Dam and 13% of yearlings passed from October - December. For comparison, in 2014 we captured 663 yearlings; most passed the dam in the spring (n = 630 from March – May), and only 4% of the yearlings passed from October – December. In 2015 the maximum reservoir pool elevation reached 1,604 ft compared to 1,691 ft in 2014.

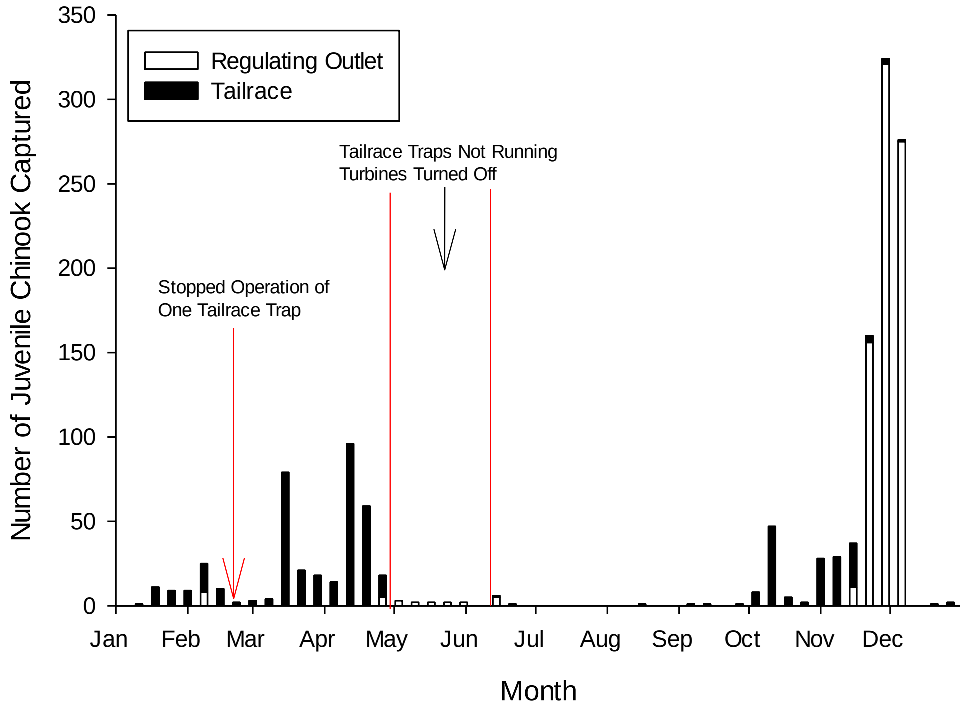

Figure 25. Weekly catch of unmarked juvenile spring Chinook salmon (subyearlings and yearlings) captured below Cougar Dam in rotary screw traps, 2015.

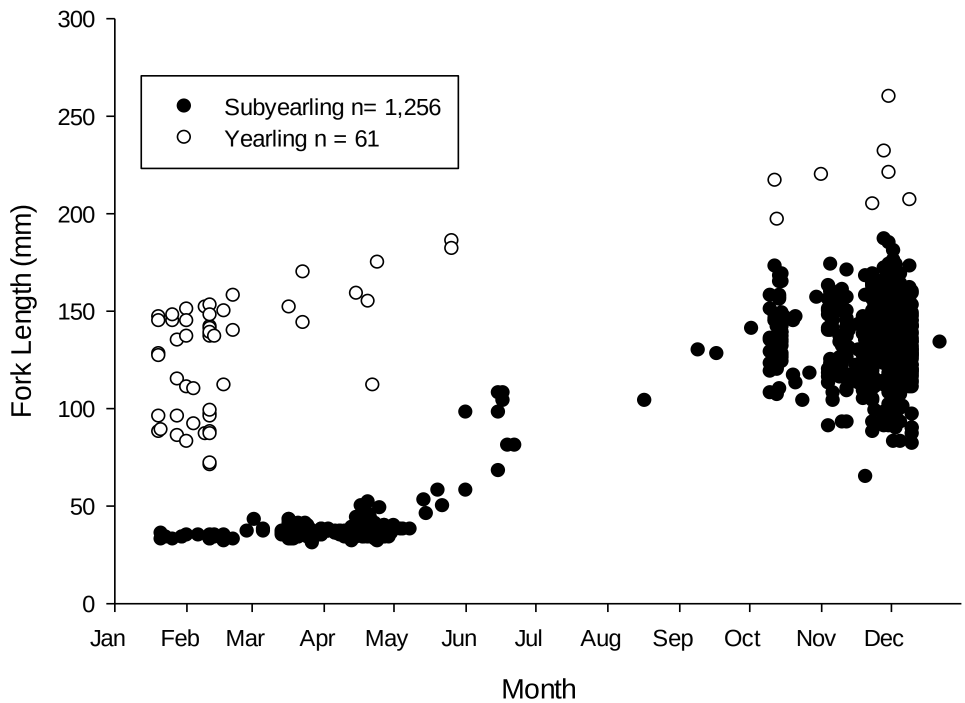

Figure 26. **Relationship between fork length and capture date for unmarked juvenile Chinook salmon sampled below Cougar Dam, 2015**.

Abundance Estimates of Outmigrants

The Breitenbush River upstream of Detroit Reservoir – We captured sufficient numbers of fish to provide an abundance estimate in 2015 (2014 BY) even though the trap only operated through June 19, when flows became too low to spin the trap. Weekly trap efficiencies ranged from 2.9% to 9.3% with a weighted annual TE of 4.8% for 2015. We estimated that 55,951 (95% CI ± 10,457) subyearlings (2014 BY) migrated past our screw trap between January and June 19, 2015 with a vast majority (96%) moving into Detroit Reservoir as fry from February through April (Figure 27). The last week of trapping at this site (June 8 – 19) we only captured a single Chinook. Additional Chinook subyearlings certainly moved past the trapping location from June through December but are not included in this estimate. We suspect that few fish moved out in the summer and winter based on previous information collected from the same site. In 2011 we observed a similar migration pattern and captured 1,036 subyearling Chinook. Only eighteen Chinook were captured after June 15 even though we operated the trap through mid-November. Therefore, we believe the 2015 Breitenbush abundance estimate to be a reasonable estimate of the number of subyearlings that entered Detroit Reservoir.

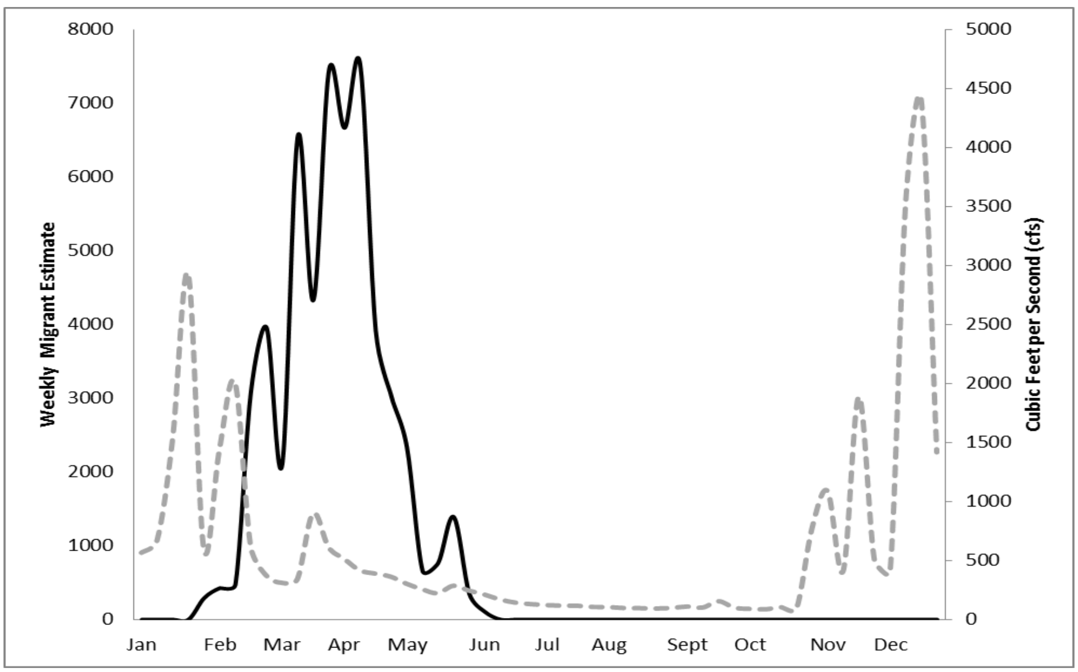

Figure 27. The estimated number of subyearling spring Chinook salmon migrating past the Breitenbush River trap and maximum flow level in 2015, summarized by week. The estimated number of subyearlings is represented by the solid black line and corresponding flow is represented by the dotted grey line.

The South Fork McKenzie River upstream of Cougar Reservoir – The South Fork McKenzie trap was the only upstream trapping site where we captured sufficient numbers of fish to provide an adequately robust abundance estimate. Weekly trap efficiencies ranged from 1.1% to 10.9% with a weighted annual TE of 2.3% for 2015. We estimated that 219,755 (95% CI ± 42,166) subyearlings (2014 BY) migrated past our screw trap and into Cougar Reservoir between January and December 2015 (Table 6). Most (90%) subyearlings moved into Cougar Reservoir as fry from March through May. Fry movement observed during the peak of the fry migration appeared to be somewhat correlated to stream flow in the South Fork McKenzie (USGS gauging station 14159200 near Rainbow; Figure 28). Once the fry had emerged, changes in weekly stream flow corresponded to changes in fry captured in the trap.

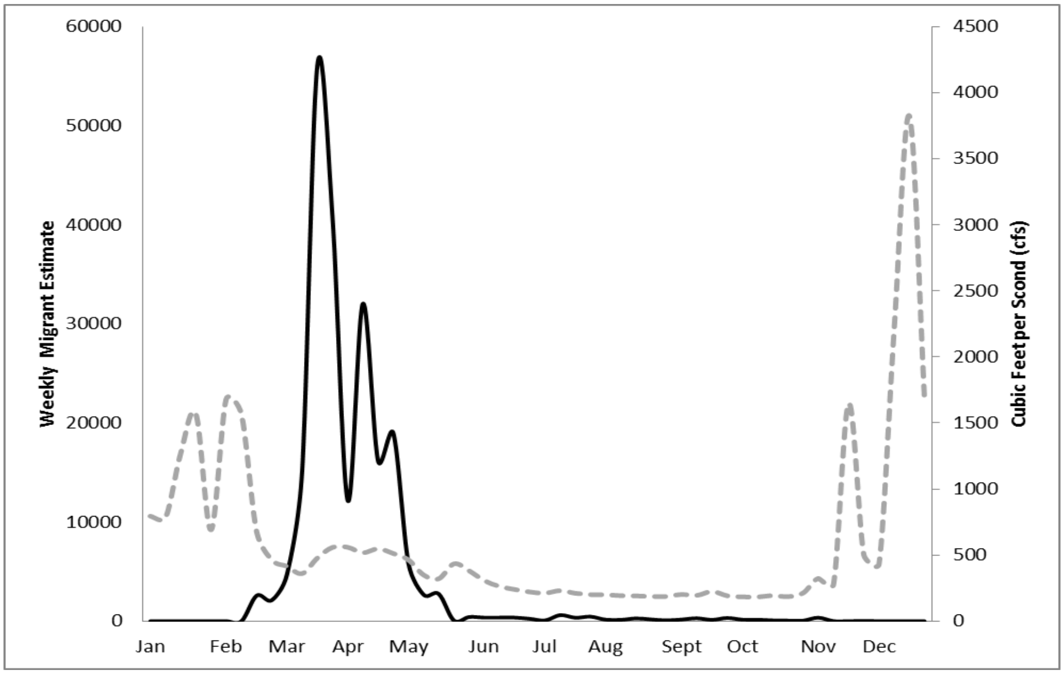

Figure 28. The estimated number of subyearling spring Chinook salmon migrating past the South Fork McKenzie trap and maximum flow level in 2015, summarized by week. Estimated number of subyearlings is represented by the solid black line and corresponding flow is represented by the dotted grey line.

Table 6. Annual estimates of the number of juvenile Chinook salmon migrating past the South Fork McKenzie screw trap upstream of Cougar Reservoir. Female spawner and redd data are from Sharpe et al. (2015).

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	557,526	±66,031	448	249	33
2013	415,741	±56,164	337	146[a]	--[b]
2014	219,755	±42,166	462	222	--

[a] A storm event in fall 2013 near peak spawn may have decreased redd numbers by making redds unidentifiable to surveyors (flattening) (2013 BY).
[b] Redds below trap were not surveyed.

Below Cougar Dam – Traps downstream of Cougar Dam were the only below-dam traps where we recaptured a sufficient number of fish to provide an abundance estimate. Weekly trap efficiencies ranged from 6.2 to 10.6 % with a weighted annual TE of 7.9% for the two turbine tailrace traps (acting as a single unit). Efficiencies for the trap in the regulating outlet ranged from 2.5 to 3.7 % with a weighted annual TE of 3.4%. We estimated that 5,862 (95% CI ± 2,036) live subyearling Chinook (2014 BY) exited Cougar dam through the turbines, and 33,078 (95% CI ± 25,211) passed using the regulating outlet in 2015 (Figure 29). We used the 2015 weighted annual trap efficiencies for each of the routes and catch information through December 31, 2015 so it is likely that an unknown number of additional fish from the 2014 BY exited the dam in the spring of 2016 as yearlings and were unaccounted for in this estimate. We are unable to estimate this number for the 2014 BY due to increases in discharge from Cougar Dam precluding trap operation as Cougar Reservoir was drained to a much lower level than usual (forebay elevation 1,455 ft) to facilitate repair and cleaning of the screen grates on the front of the temperature control tower. This included increased discharge from the regulating outlet starting on January 15, 2016 and opening of the diversion tunnel on March 3, 2016.

Although confidence intervals show that our estimates lack a high degree of precision, the South Fork McKenzie is the only sub-basin where we were able to make an estimate of comparative survival. There are several reasons for the wide confidence bounds for estimates below the dam. Discharge conditions below the dam are highly variable due to changing discharge from the various outlets. This variability is reflected in our trap efficiency estimates. With already low trap efficiencies, small changes in TE can have a large impact on the abundance estimates. It should also be noted that fish released for TE estimates below dams are released at the water surface rather than at a depth consistent with the mid-outflow discharge from the dam, so TE estimates may not reflect the exact discharge conditions of fish exiting the dam.

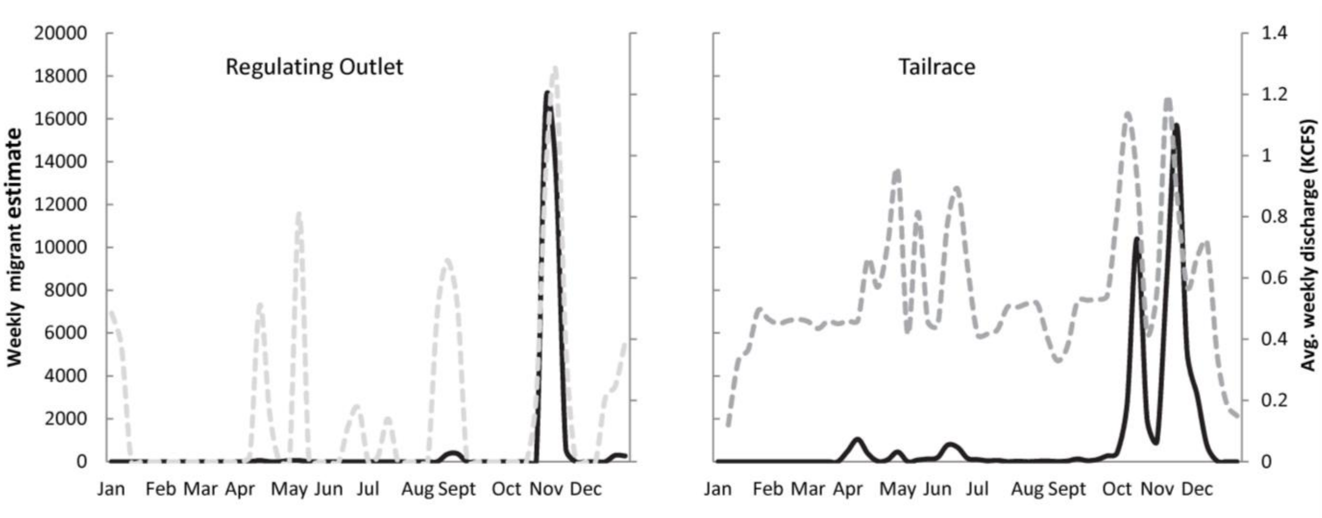

Figure 29. Estimated number of live subyearling spring Chinook salmon migrating past the Cougar Dam regulating outlet and tailrace, and mean discharge in 2015, summarized by week. Estimated number of subyearlings is represented by the solid black line and corresponding flow is represented by the dotted grey line.

We estimated 38,940 (95% CI ± 25,293) juvenile Chinook salmon from the 2014 BY survived to downstream of Cougar Dam. This estimate incorporates natural mortality incurred through predation, stochastic environmental conditions, parasites, disease while rearing in the reservoir, and dam-associated mortality. Cougar Reservoir has the fewest piscivorous fish species of any of the reservoirs in the upper Willamette basin (Lookout Point, Foster, and Detroit) and the lowest abundance of predators (Monzyk et al. 2012, 2013). The estimate of juvenile Chinook salmon exiting Cougar Dam does not include delayed dam passage mortality from potential complications such as mechanical injuries, barotrauma and gas bubble disease or complications facilitated by reservoir rearing such as increased parasite infection intensity (Monzyk et al. 2015b). Using the above and below dam estimates, we concluded ~ 17.7% (4.5-37.3%) of the Chinook salmon migrating past the screw trap upstream of Cougar Reservoir in 2015 (2014 BY) survived to below Cougar Dam. The estimated proportion of survivors is very similar to our ~17.5% (11.6 – 25.0%) estimate from 2013 for the 2012 BY.

Several important caveats need to be considered when interpreting these results. First, our subyearling estimate above the dam does not include production from redds below our trap site in some years or the number of migrants that passed the trapping site prior to trap installation, but those migrants would be included in estimates below the dam. Second, the confidence intervals are very broad for the below dam estimates and interpretation of the proportion of survivors should not be used as a definitive number but more as a framework within which we can begin to compare large changes in survival over time. In 2013 we suspected the estimate below the dam was potentially overestimated by as much 25,000 (Romer et al. 2014), due to peculiar, lower trap efficiencies during periods of high catch where we suspected crews were overwhelmed by the number of small fish in the trap and missed identifying recaptured fish that had been clipped for trap efficiency. We suggested that the lower end of the 95% confidence interval for the percent of subyearlings surviving reservoir rearing and dam passage (11.6%) may have reflected a more accurate estimate. In 2015 (2014 BY) we were not able to incorporate the number of yearlings that exited the dam in the spring of 2016 due to altered dam operations (increased discharge, opening of diversion tunnel) so the estimate may have been underestimated. We plan to refine our trap efficiency estimates in relation to discharge as we collect additional years of data which should improve our below-dam estimates.

Finally, our estimates of total cohort-wide project survival should not be confused with fry-to-smolt survival estimates, which have been estimated at 10.1% (calculated from many published and unpublished estimates for naturally rearing salmon populations) for Chinook salmon, but are known to vary among populations (Quinn 2005, Table 15-1). Reasons that estimates for cohort-wide project survival cannot be compared to fry-to-smolt survival include: 1) our data are collected throughout the year and both estimates include multiple life-history stages; and 2) most fish from any given brood year pass the dam in the fall as subyearlings, and whether or not those fish are "smolts" is unknown.

Conclusions

The 2015 migration year was marked by an earlier emergence timing of Chinook salmon fry compared to previous years. Warm stream temperatures associated with drought conditions appeared to have accelerated embryo development in 2015. Median migration date was about a month earlier than usual for subyearlings in South Fork McKenzie River above Cougar Reservoir and about two weeks earlier in the North Santiam River above Detroit Reservoir (Appendix B; Table B2).

Long-term Chinook salmon migration trends in the NFMF and Middle Fork Willamette above Hills Creek Reservoir are not possible to discern yet since this was our first year operating traps in these locations. It is interesting to note that these river systems (and to a lesser extent the North Santiam River), had more fall parr and yearlings caught in traps compared to the South Santiam and South Fork McKenzie rivers. These river systems generally have more deep pool habitat between spawning areas that could explain why more fish appear to rear for longer period in the streams. Additional years of trap operations at these sites will help discern migration trends.

Juvenile steelhead in the South Santiam River demonstrated considerable variability in the age they entered Foster Reservoir. While in most years, age-0 steelhead comprise the majority of fish caught in our trap, in 2015 age-0, age-1 and age-2 fish were caught in relatively equal numbers. Juvenile steelhead can rear in Foster Reservoir for up to 24 months before exiting the dam. In the spring, age-1 juveniles appear to outnumber age-2 smolts rearing in the reservoir but based on PIT-tag detections, the majority of steelhead leaving the reservoir are age-2 smolts. Age-0 and age-1 juveniles also leave the reservoir in the fall but the relative size of this fall outmigration is unclear compared to the spring.

As reintroduction of adult winter steelhead above Detroit Reservoir proceeds in the near future, it will be important to know the age at which juvenile offspring enter and leave the reservoir. The North Santiam and Breitenbush rivers contain more rearing habitat than the South Santiam River (R2 Resource Consultants 2007). Differences in juvenile rearing capacity between the river systems may result in older (age-2) fish comprising the majority of fish entering Detroit Reservoir.

Recommended Future Directions

Our data demonstrated that substantial numbers of Chinook salmon and steelhead can be consistently produced above the dams. These fish contribute to recovery and suggest reintroduction efforts can be successful given adequate survival. Currently, WVP dams are operated for the purposes of flood control and power generation, and the impoundments and associated project operations delay the migration of juvenile salmonids (Romer et al. 2014, Figure 4). Downstream passage structures are planned for many of the WVP dams. In the interim, we suggest facilitating subbasin-specific outmigration through operations such as delayed refill in the spring whenever possible. We hypothesize that increased early passage of smaller fish would likely also help mitigate the potential risks of copepod infection and predation risks in associated with reservoir-rearing (Monzyk et al. 2014; 2015b), and smaller fish would likely survive dam passage at a higher rate (Taylor 2000; Normandeau 2010; Keefer et al. 2011; Zymonas et al. 2011).

We suggest the continued operation of screw traps will provide information that will inform current and future reintroduction efforts with respect to (e.g.), modified transport strategies, development of release sites, spatial distribution of outplanted fish, and steelhead reintroduction. Trapping data collected above and below Cougar Dam allow comparison of abundance estimates to provide a baseline measure of cohort-wide project survival that will benefit post-effectiveness analysis of fish passage improvements at the dam. Screw traps also provide information on stochastic events (e.g., high flow events causing year-class failures) that are useful in interpreting results of other RM&E efforts such as recent genetic parentage analysis investigating total lifetime fitness of transported adult Chinook above Foster Reservoir.

Our data and the parentage analysis of Chinook salmon above Foster Reservoir (O'Malley et al. 2015) strongly suggest a near complete year-class failure in the 2010 BY. High flows in January of 2011 likely scoured redds and displaced newly emerged alevins. The river above Foster Reservoir has a deeply incised channel and most of the accessible spawning substrate is perched on bedrock. The South Santiam River has been in this condition since the 1930s, according to a Bureau of Fisheries stream habitat report (McIntosh et al. 1990) and was recently corroborated by a watershed assessment conducted in 2000 (South Santiam Watershed Council 2000) which stated that:

> "In 1856, a large fire in the watershed loaded the South Santiam stream channels with lots of wood which caused an aggradation of the channels. Most of this large wood component was removed by subsequent fires, flood events, and, more recently, timber salvage harvest. One result was downcutting in the channels and today many channels including the South Santiam River run mostly on bedrock. This creates high energy stream flows that affect the ability of juvenile fish to occupy the habitat. During high winter flows they suffer a greater risk of predation and can be washed out of the streams along with essential nutrients."

Habitat improvements (e.g., large wood placement, gravel augmentation, or stream reconnection with the floodplain) that could help recruit and retain gravel during high flows that may improve spring Chinook salmon production in the South Santiam system. Historically, 85% of the spring Chinook salmon production in the South Santiam system occurred above Foster Dam (Mattson 1948 *as cited in* Wevers et al. 1992), primarily the Middle Santiam River, Quartzville Creek, and a five-mile reach upstream of the Cascadia township on the South Santiam River. With the construction of Green Peter Dam (1967) on the Middle Santiam River and Foster Dam (1968) on the South Santiam River, the South Santiam reach is currently the only area available for Chinook salmon spawning.

We will continue to operate rotary screw traps at the same locations in 2016, with the exception of the Foster Dam trap and the trap above Hills Creek Reservoir. Long-term monitoring data generated from this project will allow researchers and managers to track changes in migration and survival as they relate to changing environmental variables among years, help assess the myriad of reservoir and dam passage options proposed for juvenile fish in the upper Willamette basin, and help evaluate the success of current and future reintroduction efforts upstream of WVP reservoirs. The traps above Detroit Reservoir will be especially useful in assessing the migration timing, size, abundance, and life history of juvenile steelhead entering the reservoir from research efforts proposed for 2017.

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 2015.

Location	Subyearling	Yearling	Total
South Fork McKenzie	290	30	320
Cougar Reservoir	0	1	1
Cougar Tailrace	0	0	0
Breitenbush River[a]	0	0	0
North Santiam River	121	37	158
Detroit Reservoir	0	0	0
Big Cliff Tailrace	10	2	12
Middle Fork Willamette (above Hills Cr. Reservoir)	0	0	0
NF Middle Fork Willamette	75	0	0
Lookout Point Reservoir	0	0	0
South Santiam River	7	5	12
Foster Reservoir	36	3	39
Foster Tailrace	2	0	2
Total	541	78	619

[a] None of the Chinook captured in the Breitenbush River were large enough to tag in 2015

Table A2. Number of juvenile Chinook salmon PIT-tagged at screw traps and reservoirs, 2010-2015.

Location	2010	2011	2012	2013	2014	2015	Total
South Fk. McKenzie R.	83	615	897	1,287	812	320	4,014
Cougar Reservoir	440	547	537	84	295	1	1,904
Cougar Tailrace	--	1,072	308	14	220	0	1,614
Breitenbush R.	8	111	--	--	--	0	119
North Santiam R.	231	184	25	76	159	158	833
Detroit Reservoir	--	58	--	--	--	--	58
Detroit Tailrace	--	66	7	3	--	--	76
Big Cliff Tailrace	--	--	--	--	9	12	21
Middle Fk. Willamette	76	36	36	148	--	--	296
NFMF Willamette	109	78	177	--	--	75	439
Lookout Point Reservoir	83	72	1	5	1	0	162
South Santiam R.	67	1	12	45	40	12	177
Foster Reservoir	--	--	--	60	54	39	153
Foster Tailrace	--	2	4	25	45	2	78
Total	**1,097**	**2,842**	**2,004**	**1,747**	**1,635**	**619**	**9,944**

Table A3. Juvenile Chinook salmon PIT-tagged above and below Willamette Valley Project dams and subsequently detected at downstream recapture or interrogation sites. -- denotes years when no Chinook salmon were tagged at this location. Year refers to the year the fish were tagged. Fish detected and recaptured at Leaburg were only counted once.

Tagging Location	Recap/Interrogation Location (RKM)	Number Recaptured 2010	2011	2012	2013	2014	2015
North Santiam River	Big Cliff Tailrace	--	--	--	--	0	**1**
	Bennett	--	--	--	--	0	0
	Stayton	--	--	--	--	**1**	**1**
	Willamette Falls	**3**	**2**	0	0	0	0
	Columbia River Trawl	**1**	0	0	0	0	0
Breitenbush River	Willamette Falls	0	**2**	--	--	--	0
Detroit Reservoir	Willamette Falls	0	**1**	0	0	--	--
Detroit Tailrace	Willamette Falls	0	**1**	0	0	0	--
Big Cliff Tailrace	Bennett	--	--	--	--	--	1
	Stayton	--	--	--	--	--	1
South Santiam River	Willamette Falls	**4**	0	0	**2**	**3**	**2**
	Will. Falls ADULT	0	0	**1**	0	0	0
Foster Reservoir	Foster Weir	--	--	--	--	**1**	**2**
	Lebanon Dam	--	--	--	--	--	**8**
	Willamette Falls	--	--	--	**1**	0	**6**
Foster Tailrace	Willamette Falls	--	--	0	4	6	0
SF McKenzie River	Cougar Reservoir	0	**4**	0	0	0	0
	Cougar Tailrace	0	**10**	**14**	**19**	**4**	0
	Leaburg	0	**15**	**23**	**53**	**18**	**1**
	Walterville	--	0	**19**	**18**	**6**	0
	Willamette R3 (175-301)	0	0	**1**	0	0	0
	Willamette Falls	0	**2**	**10**	**3**	4	0
	Columbia River Trawl	0	**1**	0	**2**	0	0
	Will. Falls ADULT	0	1	0	0	0	0
Cougar Reservoir	Cougar Tailrace	**5**	**5**	**8**	1	8	--
	Leaburg	**23**	**5**	**14**	**6**	**15**	--
	Walterville	--	**2**	**9**	**2**	0	--
	Willamette Falls	**3**	**2**	**3**	**2**	0	--
	Columbia River Trawl	0	0	0	0	0	--
	Will. Falls ADULT	0	**1**	**2**	0	0	--
Cougar Tailrace	Leaburg	0	**204**	**51**	**5**	**77**	--
	Walterville	0	**23**	**3**	**4**	**12**	--
	Willamette Falls	0	**12**	**4**	**1**	**3**	--
	Columbia River Trawl	0	**1**	0	0	0	--
	East Sand Island	0	0	**1**	0	0	--
	Will. Falls ADULT	0	**1**	**1**	0	0	--
	Cougar Trap & Haul	0	**1**	0	0	0	--
NFMF Willamette River	Willamette Falls	--	**1**	**2**	--	--	0
	Columbia River Trawl	--	0	**1**	--	--	0
	Will. Falls ADULT	--	**1**	0	--	--	0

Middle Fork Willamette River	Lookout Point Reservoir	0	0	**2**	**2**	**--**	**--**
	Willamette R3 (175-301)	0	0	0	**2**	**--**	**--**
	Willamette Falls	0	0	0	**3**	**--**	**--**
	Columbia River Trawl	0	0	0	0	--	--
	East Sand Island	**1**	0	0	0	--	--
Lookout Point Reservoir	Willamette Falls	**1**	0	0	0	--	--
	East Sand Island	0	0	0	0	--	--

Table A4. Number of juvenile *O. mykiss* PIT-tagged in the South Santiam sub-basin, 2011-2015.

Location	2011	2012	2013	2014	2015	Total
South Santiam	205	321	361	1,149	1,098	3,134
Foster Reservoir	--	--	430	498	346	1,274
Foster Tailrace	--	49	9	155	24	237
Total	**205**	**370**	**800**	**1,802**	**1,468**	**4,645**

Table A5. Juvenile *O. mykiss* PIT-tagged above and below Foster Dam on the South Santiam River and subsequently detected at downstream recapture or interrogation sites. -- denotes years when no *O. mykiss* were tagged at this location. Year refers to the year the fish were tagged.

Tagging Location	Recap/Interrogation Location (RKM)	2011	2012	2013	2014	2015
South Santiam River	Foster Reservoir	--	--	**3**	**11**	**3**
	Foster Weir	--	--	**2**	**8**	**35**
	Foster Tailrace	--	0	0	**4**	0
	Lebanon Dam	--	**--**	**--**	**9**	**33**
	Willamette Falls	0	**1**	**2**	**19**	**21**
	Columbia River	**2**	0	0	**3**	**1**
	East Sand Island	**1**	0	0	0	0
Foster Reservoir	Foster Reservoir	--	--	**6**	**17**	0
	Foster Weir	**--**	--	**1**	**17**	**22**
	Foster Tailrace	--	--	0	**2**	0
	Lebanon Dam	--	--	**--**	**1**	**9**
	Willamette Falls	--	--	**15**	**7**	**4**
	Columbia River	--	--	**2**	**2**	0
	East Sand Island	--	--	**3**	0	0
Foster Tailrace	Willamette Falls	--	0	0	**7**	0
	Columbia River	--	0	0	**1**	0
	East Sand Island	--	0	**1**	0	0

Appendix B. Basin-wide information.

Table B1. Number of adult female spring Chinook salmon outplanted upstream of Willamette Valley reservoirs, 2009-2014 (Cannon et al. 2010, 2011; Sharpe et al. 2013, 2014; ODFW, unpublished data).

Reservoir	River	2009	2010	2011	2012	2013	2014
Detroit	Breitenbush	36	397	0	23*	144*	159
	North Santiam	111	746	63	98	540	139
Foster	South Santiam	172	231	597	444	428	196
Cougar	South Fork McKenzie	629	320	336	448	337	464
Lookout Point	NFMF Willamette	361	573	787	1,208	931	459

*Fish were released at Kane's Marina in Detroit Reservoir at the mouth of the Breitenbush River; subsequent surveys demonstrated nearly all migrated up the North Santiam River.

Table B2. Median migration date by year for subyearling Chinook salmon migrating past screw trap sites, 2010-2015.

	Median Migration Date					
Location	2010	2011	2012	2013	2014	2015
North Santiam	--	May 6	May 14	May 14	May 8	Apr 20
Breitenbush	--	Mar 8	--	--	--	Mar 27
South Santiam	--	--	Mar 7	Feb 28	--[a]	Jan 30
South Fk McKenzie	May 1	May 16	May 16	Apr 26	May 8	Apr 9
Middle Fk Willamette (above Hills Cr. Res.)	--	--	--	--	--	Mar 29
North Fk Middle Fk	--	--	--	--	--	May 16
Middle Fk Willamette (at Westfir)	--	Mar 28	Apr 13	Apr 4	Apr 9	--

[a] Trap was not running for a 26-day window during what has been the peak of outmigration in previous years.

Table B3. Summary of all abundance estimates for juvenile Chinook salmon above and below dams for Willamette River sub-basins where estimate criteria were met, brood years 2010-2014.

Location	Brood Year	Abundance Est.	95% CI
North Santiam	2010	587,960	±193,708
Breitenbush	2014	55,951	±10,457
South Fork McKenzie River	2009	685,723	±72,519
	2010	152,159	±26,665
	2011	228,241	±34,715
	2012	557,526	±66,031
	2013	415,741	±56,164
	2014	219,755	±42,166
Below Cougar Dam	2012	97,628	±25,420
	2014	38,940[a]	±25,293

[a] Estimate does not include yearlings from this brood year that migrated in the spring of 2016.
2012 BY 17.5% survived to below dam (11.6-25.0%)
2014 BY 17.7 % survived to below dam (4.5-37.3%)

Table B4. Peak months of juvenile steelhead and subyearling spring Chinook salmon migration into reservoirs in all rivers with rotary screw traps (2010-2015).

River	Peak months of subyearling migration	Species
North Santiam	March - June	Spring Chinook salmon
Breitenbush	February - April	Spring Chinook salmon
South Santiam[1]	January - March	Spring Chinook salmon
	July – November[2]	Winter Steelhead
Middle Fork Willamette (above Hills Cr. Reservoir)	March - April	Spring Chinook salmon
Middle Fork Willamette - Westfir	February - June	Spring Chinook salmon
North Fk Middle Fk Willamette	March - May September - December[3]	Spring Chinook salmon
South Fork McKenzie	March - June	Spring Chinook salmon

[1] South Santiam is currently the only river where wild winter steelhead are present
[2] Includes all age-classes
[3] Only one year of data (2015). Appears to be two peaks in migration (spring, fall)

Appendix C. Below Cougar Dam.

Table C1. Number of juvenile Chinook salmon captured each month below Cougar Dam partitioned by brood year (brood years 2009-2014). Data are summarized on a 24-month scale corresponding to the typical reservoir exit timing for the entire cohort. Asterisks denote the last available month of data collection.

Life Stage	Month	2009 BY	2010 BY	2011 BY	2012 BY	2013 BY	2014 BY
Fry (< 60 mm)	Jan	0	0	0	0	0	6
Fry (< 60 mm)	Feb	0	0	0	0	24	17
Fry (< 60 mm)	Mar	0	13	6	0	26	118
Fry (< 60 mm)	Apr	9	1	6	118	18	186
Fry (< 60 mm)	May	1	1	23	60	15	8
Fry/Subyearling	Jun	127	9	25	218	34	9
Fry/Subyearling	Jul	0	17	12	20	9	0
Fry/Subyearling	Aug	80	38	380	31	4	1
Subyearling	Sep	26	19	60	60	1	2
Subyearling	Oct	60	90	250	940	137	61
Subyearling	Nov	905	942	1,068	2,605	3,113	326
Subyearling	Dec	2,155	125	1,174	272	242	525*
Yearling	Jan	373	288	6	46	15	
Yearling	Feb	72	4	2	95	29	
Yearling	Mar	62	12	2	217	3	
Yearling	Apr	242	82	35	191	4	
Yearling	May	153	20	96	73	2	
Yearling	Jun	48	5	26	3	0	
Yearling	Jul	10	0	0	1	0	
Yearling	Aug	0	0	0	0	0	
Yearling	Sep	1	0	0	0	0	
Yearling	Oct	0	2	15	2	2	
Yearling	Nov	17	13	62	24	5	
Yearling	Dec	2	6	0	3	1	
	Total	4,343	1,687	3,248	4,979	3,684	1,259

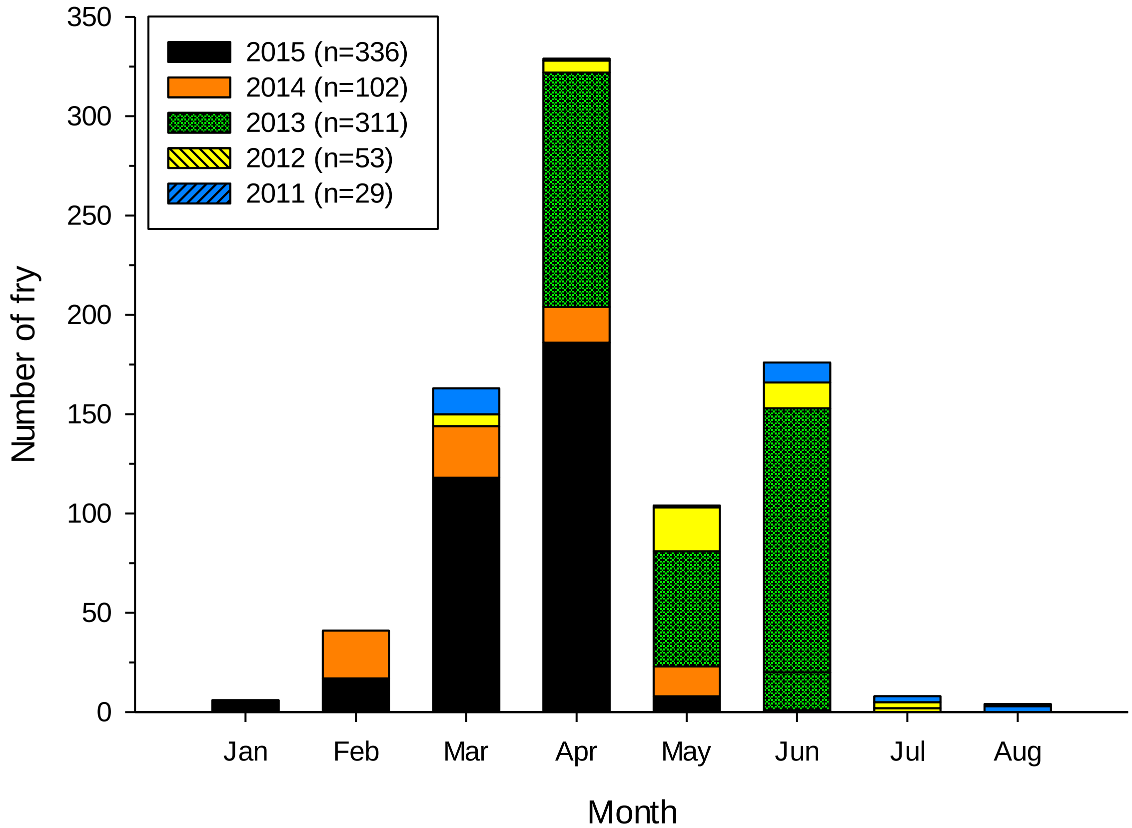

Figure C1. Number and timing of Chinook salmon fry caught in rotary screw traps located below Cougar Dam, 2011-2015. Fry were classified as fish <60 mm fork length. Numbers in parentheses are total number of fry caught for the year.

Appendix D. Dam Discharge and Pool Elevation Graphs and All Species Captured Below WVP Dams.

Table D1. Number of each species captured in the screw traps below Big Cliff Dam each month in 2015. Mysis shrimp counts are estimates. Mk = fin-marked; Unmk = unmarked.

Month	Chinook salmon Mk	Chinook salmon Unmk	Rainbow Trout Mk	Rainbow Trout Unmk	Kokanee	Mountain Whitefish	Sculpin	Pumpkinseed & Bluegill	Mysis Shrimp
JAN	1	3	0	0	8	0	1	13	50
FEB	2	40	0	0	2	0	0	1	0
MAR	0	2	0	0	1	0	0	2	100
APR	1	0	0	1	0	0	0	5	0
MAY	1	1	0	3	6	0	0	38	0
JUN	0	0	0	0	9	0	0	51	3,450
JUL	0	8	0	6	0	0	0	5	0
AUG	1	3	0	4	0	0	0	12	0
SEPT	2	0	0	1	0	0	0	11	0
OCT	6	11	0	1	0	0	10	933	0
NOV	126	50	0	1	45	0	2	312	1,000
DEC	16	23	0	2	78	1	0	0	400
TOTAL	156	141	0	19	149	1	13	1,383	5,000

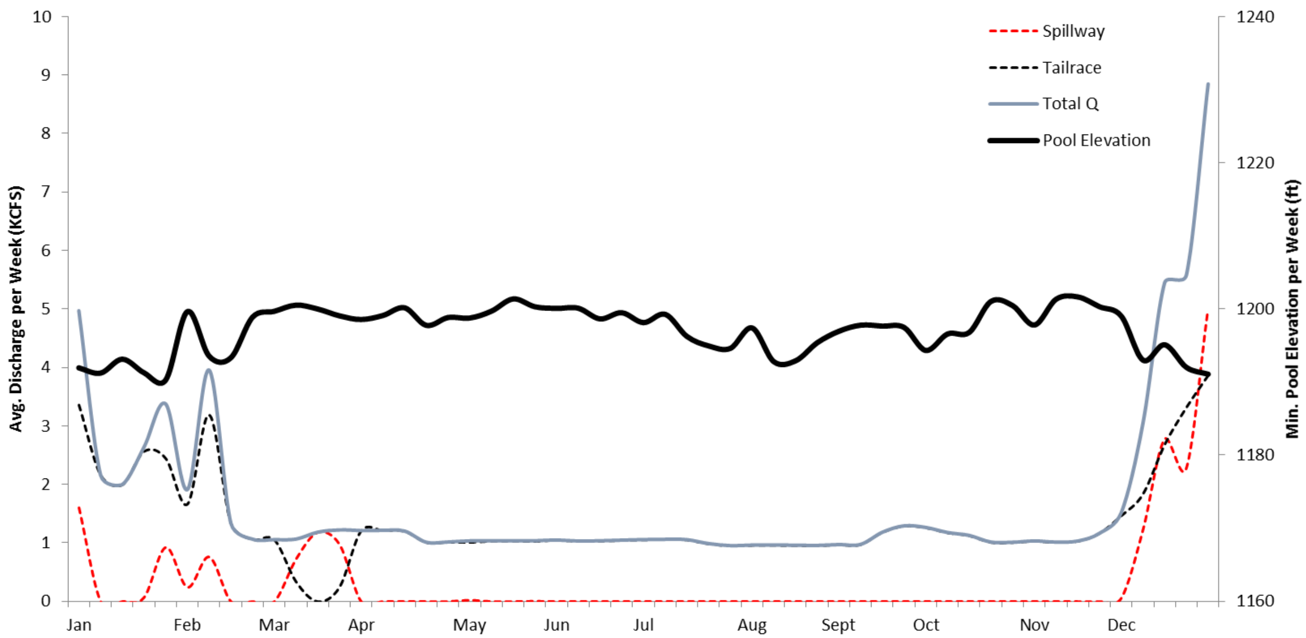

Figure D1. Big Cliff Dam discharge (Q) and reservoir pool elevation, 2015. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.

Table D2. Number of each species captured in the screw trap below Foster Dam summarized by species and month, 2015. Mk = fin-marked; Unmk = unmarked. – denotes month the trap was not operating.

	Chinook Salmon		*O. mykiss*		Kokanee	Cutthroat	Yellow Perch	Bluegill	Crappie	Largescale Sucker	Dace	Northern Pikeminnow	Brook Lamprey	Redside Shiner
Month	Mk	Unmk	Mk	Unmk										
JAN	27	3	0	0	16	0	9	0	0	0	2	0	0	0
FEB	224	5	0	1	15	0	26	0	0	0	3	0	0	0
MAR	0	5	1	0	1	0	13	0	0	0	12	0	0	0
APR	3	3	19	0	0	0	9	0	0	0	5	0	0	0
MAY	0	2	22	0	0	0	2	0	0	0	1	0	0	0
JUN	1	0	5	0	0	0	0	0	0	0	2	0	0	0
JUL	--	--	--	--	--	--	--	--	--	--	--	--	--	--
AUG	0	0	7	0	0	0	0	0	0	0	0	0	0	0
SEPT	0	0	4	1	0	0	0	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	2	0	0	0	0	0	0	0
NOV	3	0	0	3	3	0	320	0	0	0	0	102	0	0
DEC	0	10	1	21	23	0	611	0	1	11	0	399	0	0
TOTAL	258	28	59	26	58	0	992	0	1	1	25	501	0	0

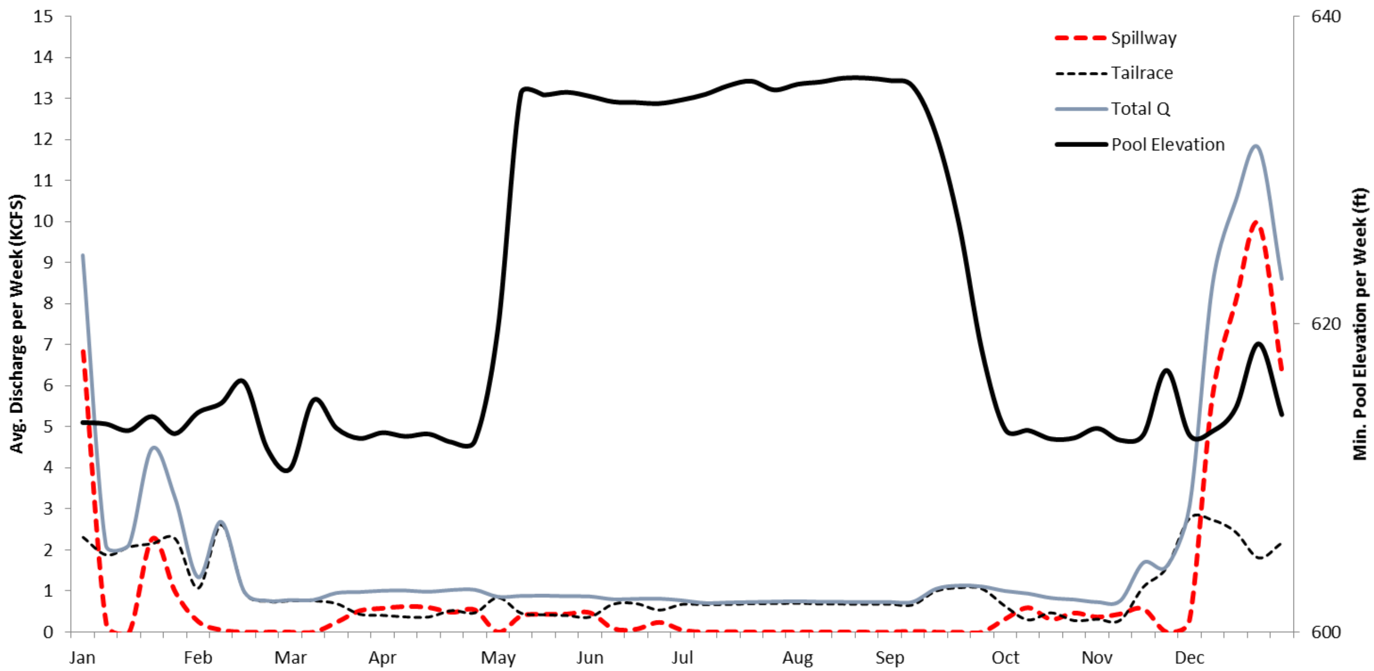

Figure D2. Foster Dam discharge (Q) and reservoir pool elevation, 2015. Discharge is reported as the weekly average and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.

Table D3. Number of each species captured in the screw trap below Lookout Point Dam summarized by species and month, 2015. Mk = fin-marked; Unmk = unmarked. -- denotes months the trap was not operating.

Month	Chinook Salmon Mk	Chinook Salmon Unmk	Rainbow Trout	Northern Pikeminnow	Bass	Crappie	Pumpkinseed & Bluegill	Sculpin	Redside Shiner	Largescale Sucker
JAN	0	9	1	0	0	3	0	0	0	0
FEB	1	1	0	0	0	3	0	2	0	1
MAR	0	0	0	0	0	0	0	1	1	0
APR	0	0	0	0	0	0	1	1	0	0
MAY	0	0	0	0	0	0	0	0	0	1
JUN	0	0	0	0	0	0	0	1	0	0
JUL	--	--	--	--	--	--	--	--	--	--
AUG	--	--	--	--	--	--	--	--	--	--
SEPT	0	0	0	0	0	0	49	0	0	0
OCT	0	0	0	0	0	0	18	0	0	0
NOV	0	0	0	0	0	2	7	0	0	0
DEC [a]	0	0	0	0	0	1	6	0	0	0
TOTAL	1	10	1	0	0	9	81	5	1	2

[a] Trap only operated 1 day (Dec 1) in December.

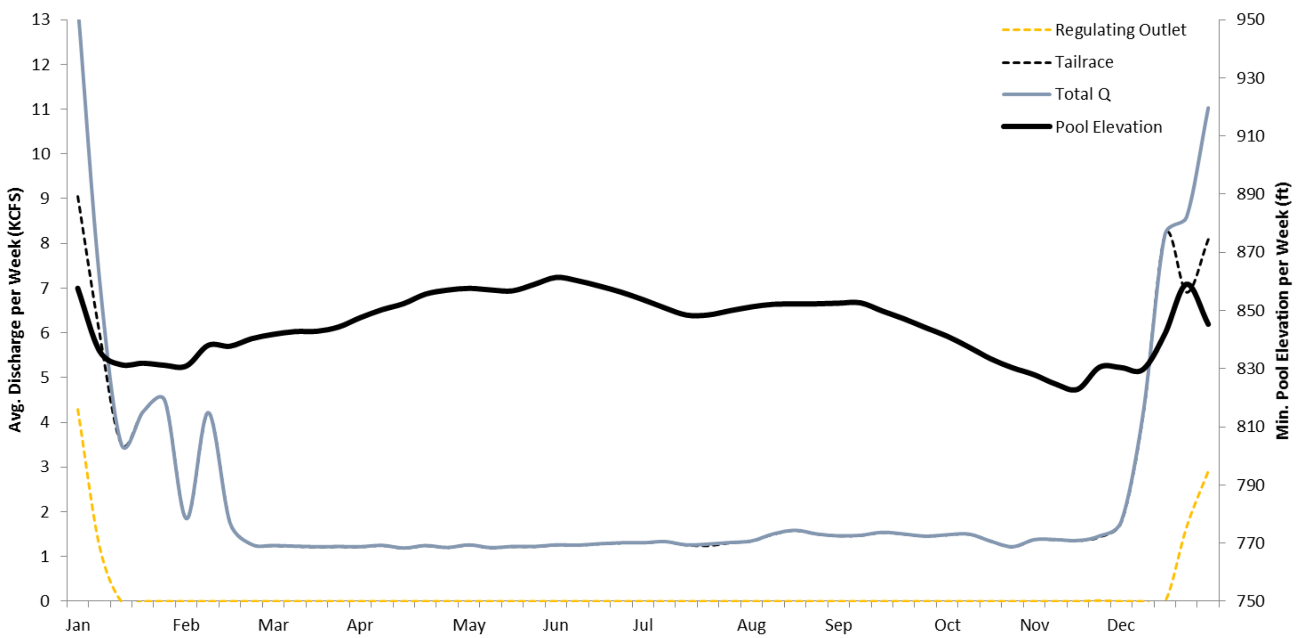

Figure D3. Lookout Point Dam discharge (Q) and reservoir pool elevation, 2015. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week.

Table D4. Number of each species captured in the screw trap below Fall Creek Dam summarized by species and month, 2015. Mk = fin-marked; Unmk = unmarked. [a] Trap restarted 9/29/15. – denotes months the trap was not operating.

Month	Chinook salmon Mk	Chinook salmon Unmk	Rainbow Trout	Cutthroat Trout	Lamprey	Pumpkinseed & Bluegill	Sculpin	Redside Shiner	Dace	Mountain Whitefish	Largescale Sucker
JAN		9	0	2	0	0	1	0	0	0	0
FEB		1	0	0	0	0	0	0	0	0	0
MAR		--	--	--	--	--	--	--	--	--	--
APR		--	--	--	--	--	--	--	--	--	--
MAY		--	--	--	--	--	--	--	--	--	--
JUN		--	--	--	--	--	--	--	--	--	--
JUL		--	--	--	--	--	--	--	--	--	--
AUG		--	--	--	--	--	--	--	--	--	--
SEPT[a]		0	1	0	1	0	0	1	0	0	0
OCT		7	0	0	0	842	0	1	0	0	2
NOV		123	0	0	0	12,088	0	1	2	1	763
DEC		0	0	0	0	0	0	0	1	0	0
TOTAL		130	1	2	1	12,930	1	3	3	1	765

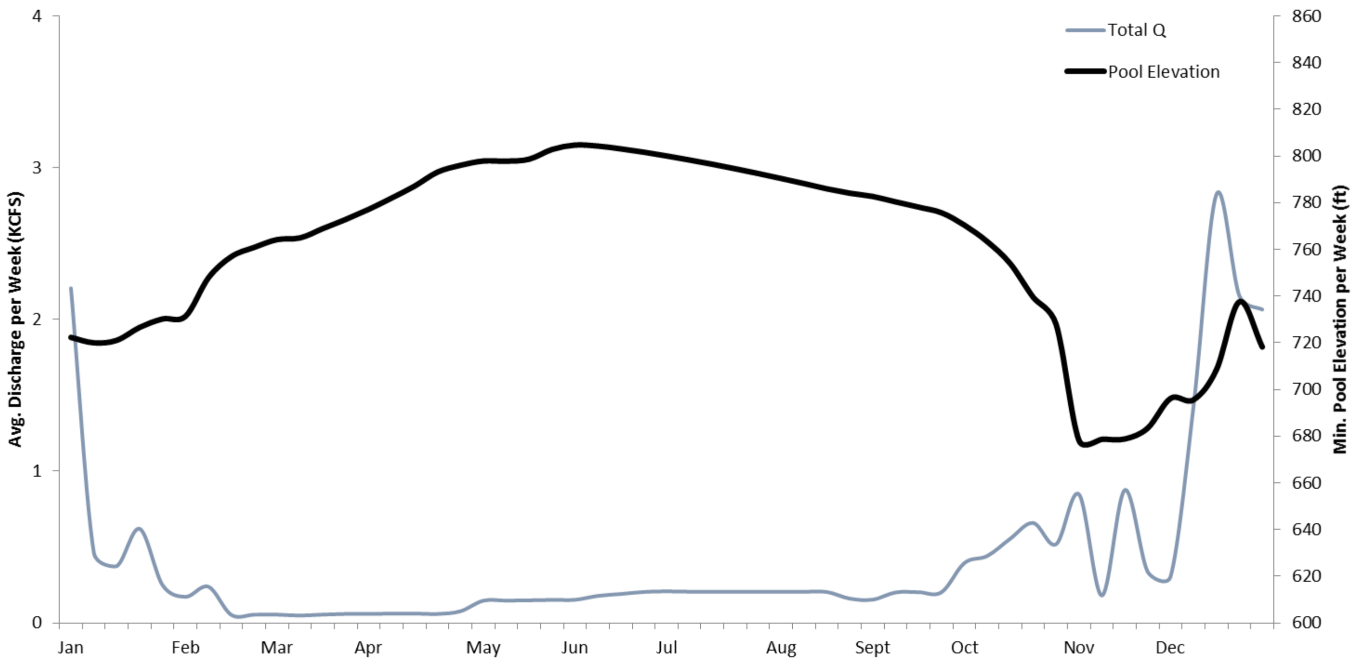

Figure D4. Fall Creek Dam discharge (Q) and reservoir pool elevation, 2015. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week.

Table D5. Number of each species captured in the screw trap below Cougar Dam summarized by species and month, 2015. All Chinook salmon and rainbow trout were unmarked.

Month	Chinook salmon	Rainbow Trout	Cutthroat	Trout Fry	Bull Trout	Mountain Whitefish	Dace	Brook Lamprey	Sculpin	Bass	Bluegill
JAN	21	1	0	0	0	0	0	0	1	0	0
FEB	46	5	0	0	0	0	0	0	0	0	0
MAR	121	2	1	0	0	0	1	0	5	0	0
APR	190	6	0	0	0	0	5	1	3	1	2
MAY	10	6	0	0	0	0	9	1	1	0	0
JUN	9	2	0	0	0	0	32	0	4	0	0
JUL	0	2	0	0	0	0	16	1	2	0	0
AUG	1	0	0	0	0	0	10	0	0	0	0
SEPT	2	0	0	0	0	0	0	0	0	0	0
OCT	63	1	0	0	0	0	0	0	0	0	0
NOV	331	0	0	0	0	0	0	0	1	0	0
DEC	526	1	0	0	0	2	0	0	0	0	0
TOTAL	1,320	26	1	0	0	2	73	3	17	1	2

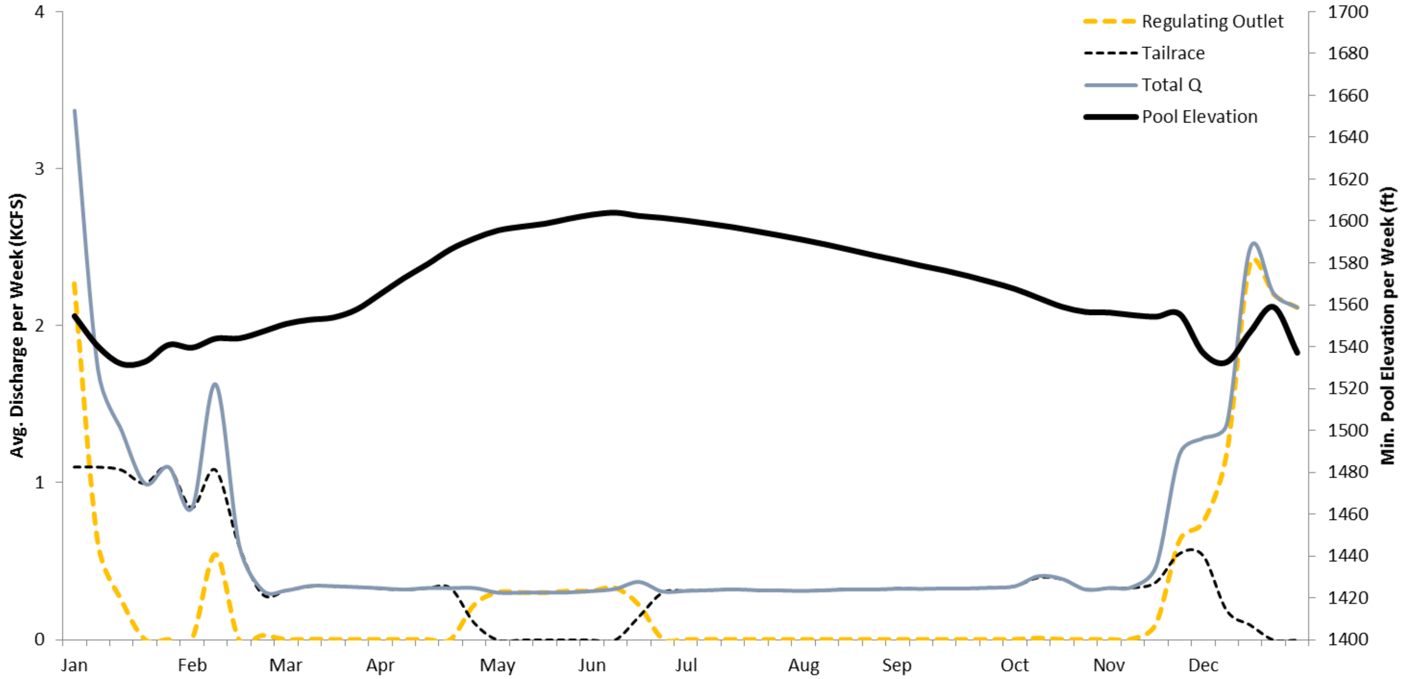

Figure D5. Cougar Dam discharge (Q) and reservoir pool elevation, 2015. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.

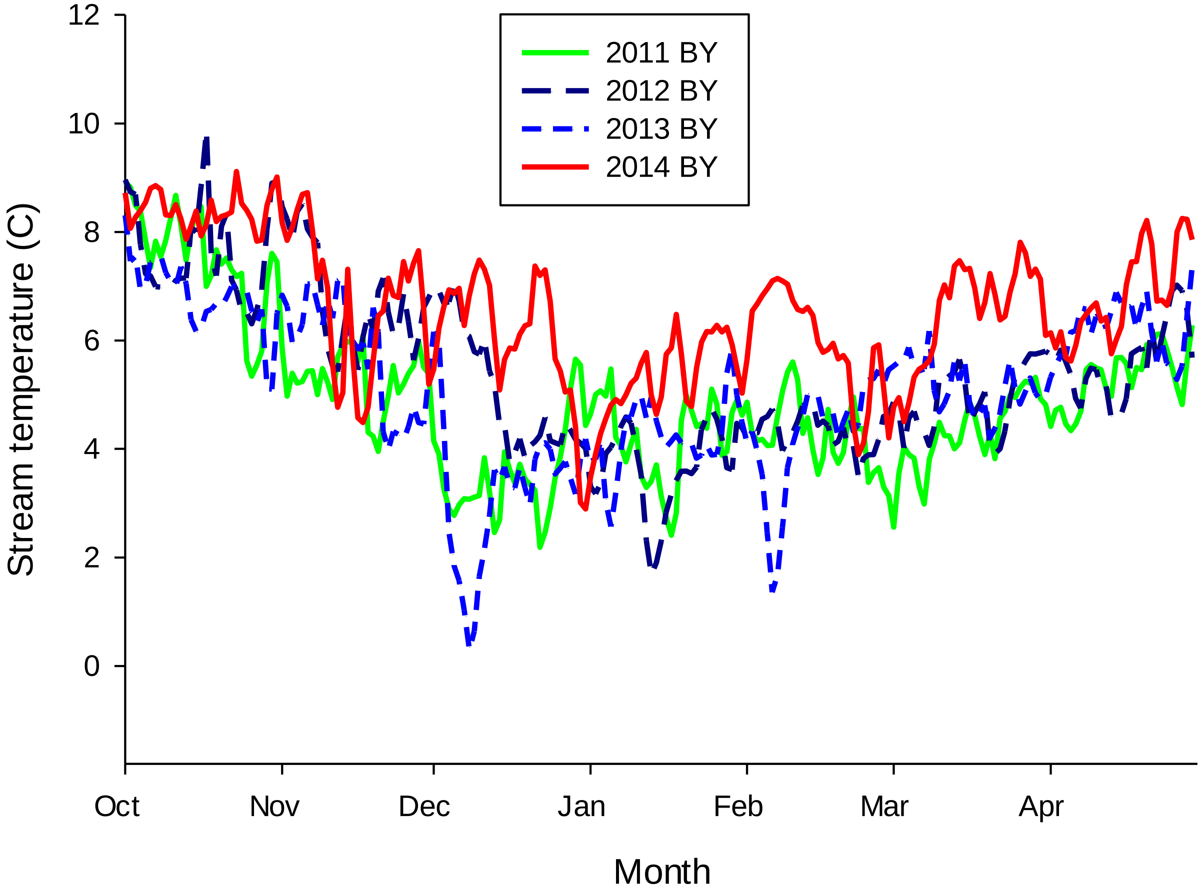

Figure E1. Mean daily stream temperatures in the South Fork McKenzie River above Cougar Dam for Chinook salmon brood years 2011-2014. Data from USGS gage station 14159200.