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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 2016 and summarize data from previous years. 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, 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 the trap operated by USACE personnel below Fall Creek Dam.

The specific 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 2016, 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 [2015 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 un-impounded tributaries of the McKenzie River. Chinook salmon fry typically entered WVP reservoirs from February through June. The average fork length (FL) of fry entering most WVP reservoirs in the spring was 35 mm, consistent with previous years.

The number of subyearlings moving past our trap in the South Fork McKenzie and into Cougar Reservoir in 2016 was estimated to be 627,876 (95% CI ± 98,638). This was the second highest estimate of production from outplanted adults. Most (90%) subyearlings moved into Cougar Reservoir as fry from March through May.

Fall parr and spring yearling Chinook salmon (2015 BY) entering reservoirs were relatively rare compared to fry at all locations. Similar to last year, the North Fork Middle Fork and the North Santiam rivers had more fall parr 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 may 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 continue migration through the reservoirs in the spring. This was consistent with 2016 data, as we captured few fry in traps below dams. Most juvenile spring Chinook salmon reared in WVP reservoirs for several months and exited as subyearlings in late fall and early winter (October – December), in conjunction with reservoir drawdown and lowered pool elevation. Based on limited downstream detections at Willamette Falls of fish marked with passive-integrated transponder tags as they exited Cougar Dam in the fall, the majority of fish (91%) quickly migrate to the Columbia Estuary within a few weeks.

Subyearlings began passing Cougar Dam in large numbers in late October to early November 2016, coinciding with an increase in dam outflow, with a secondary peak in December. At the USACE portable floating fish collector (PFFC) located in the dam forebay, subyearlings catch began in late September and peaked in October. This suggest large numbers of juveniles, possibly fall smolts, were present in the forebay (available for dam passage) beginning in September but were delayed in passing the dam until the last week in October under baseline dam operating conditions.

The South Santiam River above Foster Dam is currently the only reach above a WVP reservoir with winter steelhead production. We captured 581 juvenile *O. mykiss* in the screw trap in 2016, comprised of age-0, age-1, and age-2 fish. Age-2 fish comprised 17% of the juvenile steelhead migrants in 2016, a similar proportion to 2015 (26%). In previous years (2011-2014), age-2 fish comprised <1 to 4% of migrants. The reason for the variability in age at outmigration is uncertain.

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 under baseline conditions.

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 Big Cliff, Foster, and Cougar dams. We also summarize USACE fish data collected from the trap below Fall Creek Dam. 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 in this study were primarily progeny from adults that were trapped and hauled upstream of WVP dams. Exceptions may include production from adfluvial Chinook salmon adults (Romer and Monzyk 2014) or resident rainbow trout. 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 2016–March 2017. Included in this report are a summary and analysis of field activities implemented by ODFW on behalf of the USACE through December 31, 2016, to address requirements of RPA measures prescribed in the Willamette Project BiOp (NMFS 2008). Primary tasks included: 1) monitor juvenile salmonid outmigration to provide information on migration timing and size, and 2) estimate abundance of outmigrating UWR Chinook salmon.

Methods

Rotary Screw Traps

Above Project Traps- Traps deployed above WVP reservoirs in 2016 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 1). All rotary screw traps upstream of project reservoirs were 1.5 m in diameter, and trapping sites remained consistent with 2015 sampling locations (Table 1; Romer et al. 2016). 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, 2016). 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 Breitenbush River trap was located on U.S. Forest Service property just upstream of the USGS gaging station and was ~0.45 km upstream of the reservoir. 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).

Below Project Traps- We continued trapping efforts in 2016 below Big Cliff, Foster and Cougar dams (Table 1). We also summarized migrant data received from USACE personnel from their trap below Fall Creek Dam (Figure 1). The trap located below Lookout Point Dam was operated infrequently by the USACE in 2016, so we do not present those data here. Generally, controlled discharge from the dams allowed us to operate traps nearly every day of the year, except for during 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 2016) maintenance, safety upgrades, or when debris or substrate movement prevented the trap from rotating.

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 2). The two traps in the tailrace operate side by side (Figure 2) as a single unit. The tailrace unit operated 293 d and the RO operated 319 d (Figure 4) in 2016.

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 ceasing operations at this site; we removed the trap on April 19, 2016.

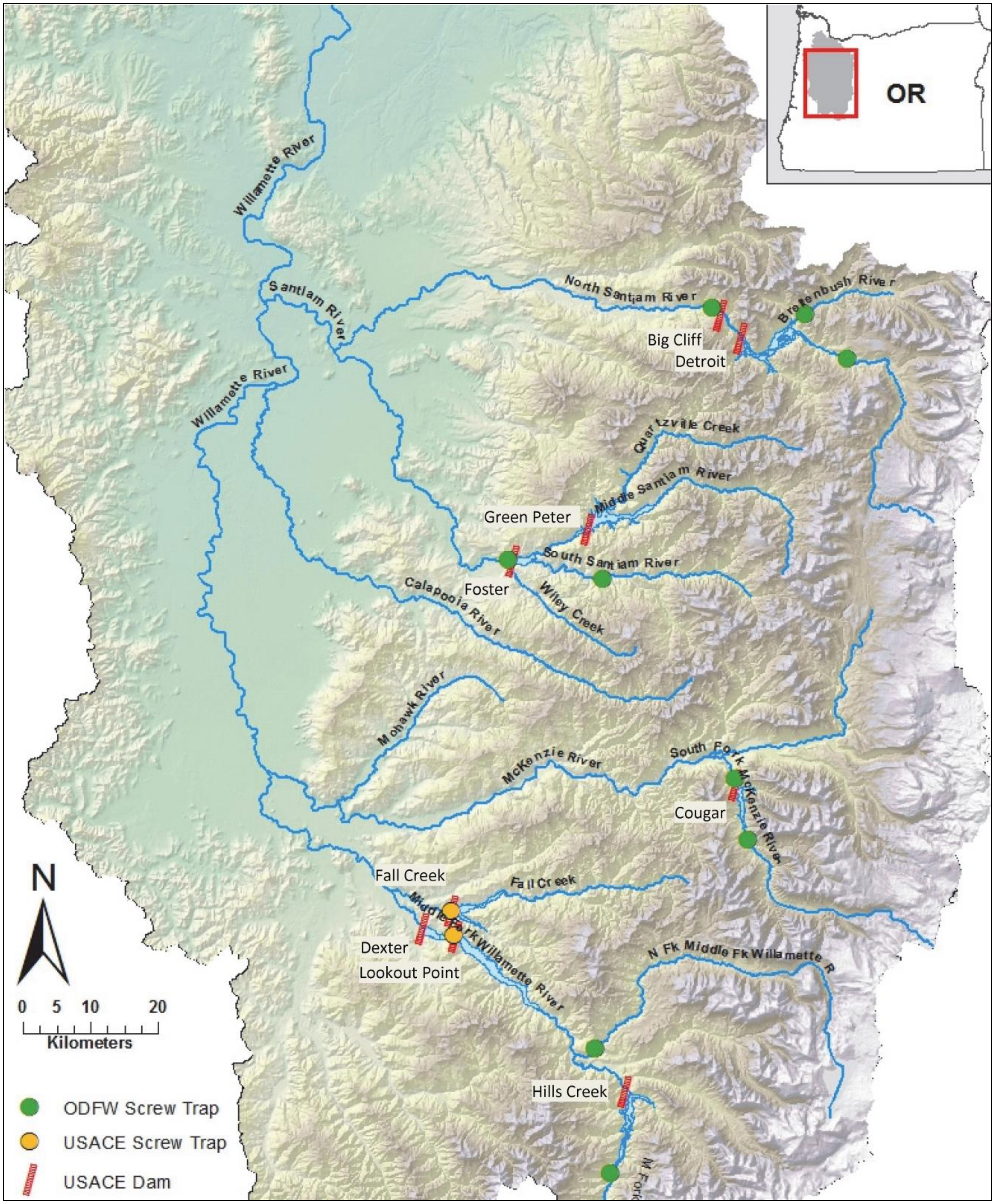

Figure 1. Locations of rotary screw traps operated by ODFW and USACE above and below Willamette Valley Project dams.

Table 1. Installation dates and location of rotary screw traps above and below Willamette Valley Project reservoirs, 2016. 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	February 19	286	0568785 4955753
North Santiam	March 3	292	0575240 4949260
South Santiam	January 2	271	0539897 4915479
South Fork McKenzie	February 29	395	0562654 4877522
North Fork Middle Fork Willamette	February 18	364	0541029 4846205
Below Dams			
Big Cliff	January 1	266	0554987 4956117
Foster	January 1	253	0526128 4917989
Cougar Tailrace	January 1	379	0560486 4886873
Cougar RO	January 1	379	0560486 4886873
Lookout Point	Did Not Operate	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. Below dam traps were positioned such that if there was sufficient flow the traps were fishing (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 reflect 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 tricaine methansulfonate (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 and were subsequently 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 (see Figures 6, 8, 10, 12, 16, 19, 21, and 23). Juveniles that hatched in spring 2016 (2015 BY) were classified as subyearlings, and yearlings were fish that hatched the previous year (2014 BY) and remained in the reservoir after January 1, 2016. Salmonids < 60 mm were considered fry. We report outmigration timing during the calendar year (January 1 – December 31, 2016). 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 (542 adults from 2014-16). The number of juvenile *O. mykiss* caught in the South Santiam trap upstream of Foster Reservoir is also usually an order of magnitude greater than in other basins where adult steelhead are not transported above dams.

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 and A2) to collect recapture and detection information (Appendix A; Table A3).

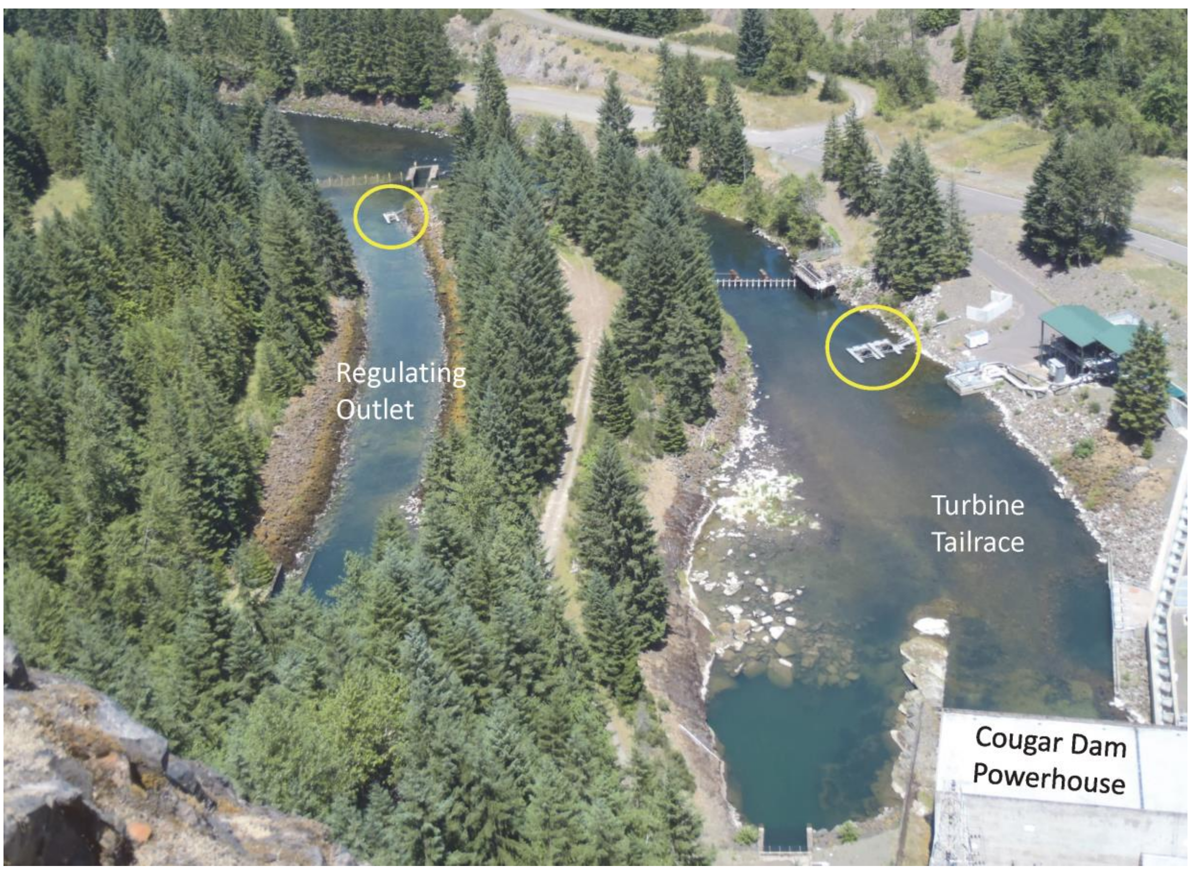

Figure 2. Rotary screw traps below Cougar Dam (1.5-m diameter in regulating outlet, 2.4-m diameter x 2 in tailrace; South Fork McKenzie River rkm 385).

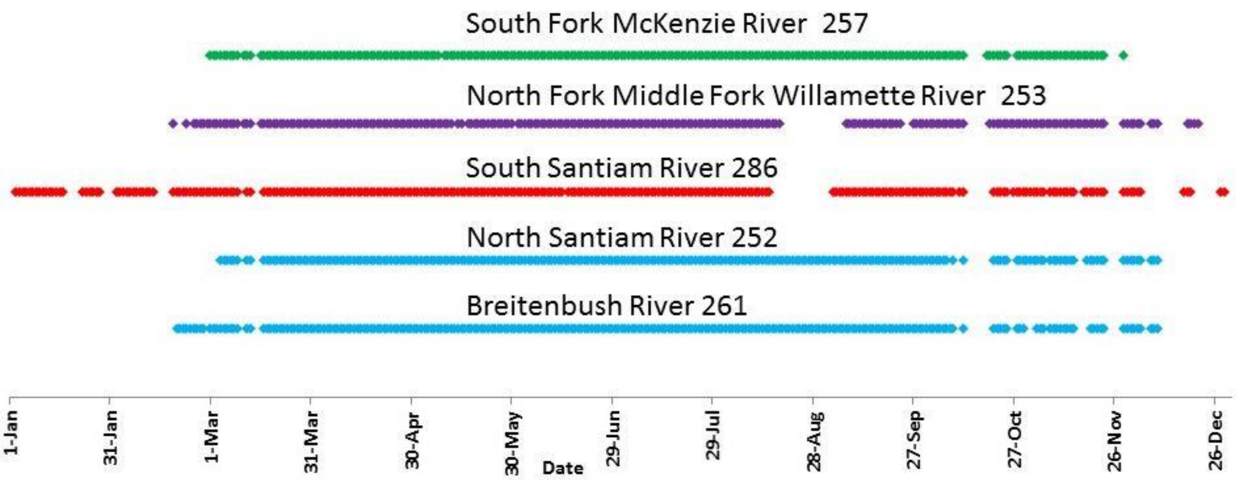

Figure 3. Screw trap operation summary for traps upstream of Willamette Valley reservoirs, 2016. Each colored dot represents one day of operation; numbers are the total days the trap operated during the calendar year.

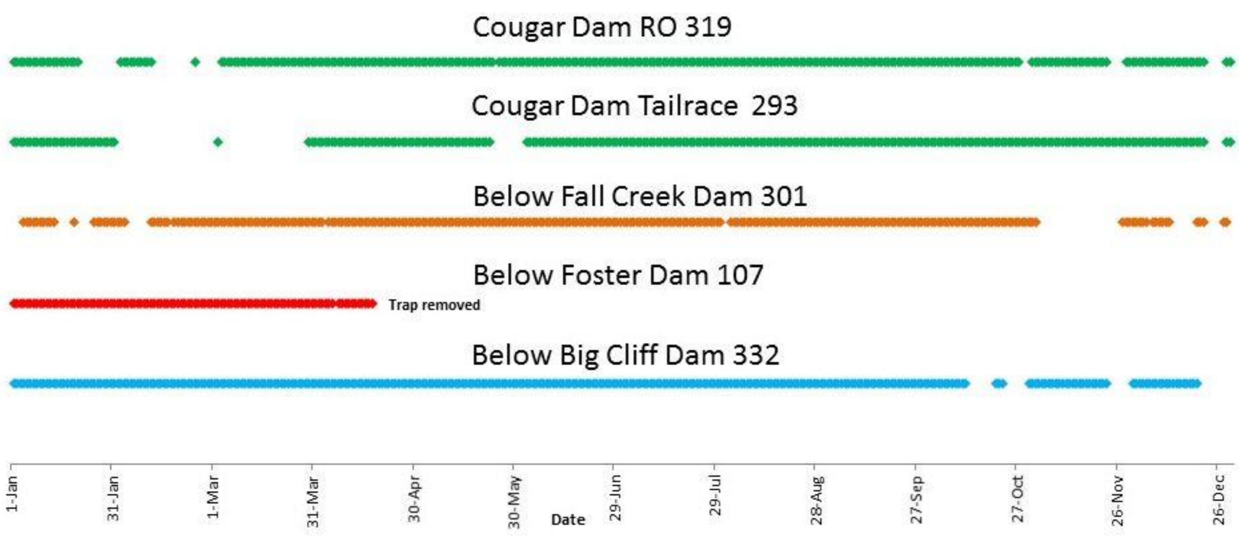

Figure 4. Screw trap operation summary for traps below dams in the upper Willamette River Basin, 2016. Each colored dot represents one day of operation; numbers are the total days the trap operated during the calendar year. Tailrace = turbine tailrace. RO = regulating outlet.

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 interquartile range of cumulative catch data for the year (between 25^{th} and 75^{th} 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. On occasion, a trap was stopped for a period of one to several days due to high flows or debris. To account for these periods in abundance estimate calculations, daily migrant catch during periods of trap stoppage was estimated as the mean number of fish captured the day before and after the stoppage period. If trap efficiency criteria were not met for a particular sub-basin, the actual number of fish captured was reported.

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 North Santiam and NFMF appeared to have a relatively larger pulse of subyearlings leaving in the fall (September – December) compared to other sub-basins, possibly owing to a greater amount of stream-rearing habitat in these sub-basins.

The greatest catch of Chinook salmon in traps below Project dams occurred primarily during late fall and early winter during reservoir drawdown and was comprised mainly of subyearlings. There were two exceptions to this pattern. At Foster Dam most Chinook salmon subyearlings were typically captured from January to April, which would have likely the case this year even though the trap was removed in mid-April. Below Big Cliff Dam in 2016, the peak of dam passage for juvenile Chinook salmon was June – September, with the peak outmigration associated with a surface spill event.

North Santiam River- We operated the screw trap in the North Santiam River above Detroit Reservoir from March 3 until December 9, 2016. The trap fished for 252 d and captured 1,288 subyearling Chinook salmon and three yearlings. The peak migration was in April (Figure 5) with a median migration date of April 27. The peak timing of downstream migrants fell within the range observed in previous years (Appendix B, Table B1; Appendix C, Figure C1). Most subyearlings (76% of our catch) entered Detroit Reservoir during March - May as fry averaging 37 mm FL (Figure 6). Similar to 2010 (2009 BY), 2013 (2012 BY) and 2014 (2013 BY), we observed a smaller pulse of subyearling movement during the fall which was not observed in 2011 and 2012 (2010 - 2011 BY; Appendix C, Figure C1). The size range for subyearlings caught throughout the 2016 season was 28-131 mm FL.

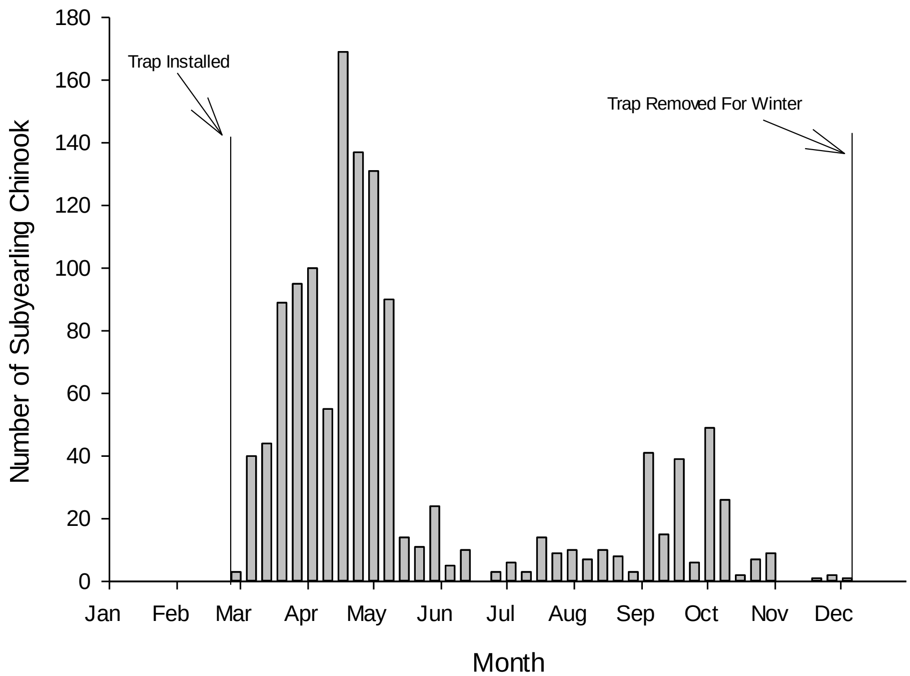

Figure 5. Weekly catch of subyearling spring Chinook salmon captured in the North Santiam trap above Detroit Reservoir, 2016.

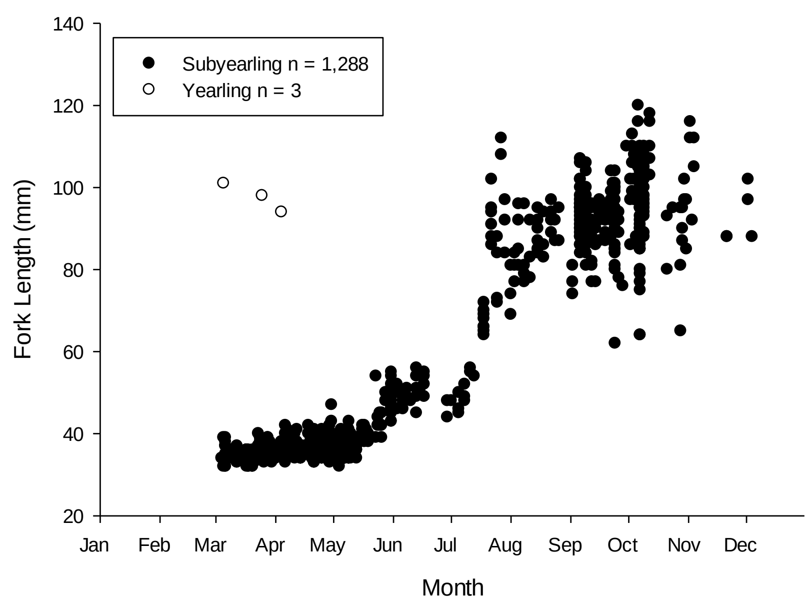

Figure 6. Fork lengths of juvenile Chinook salmon captured in the North Santiam trap above Detroit Reservoir, 2016.

Breitenbush River- We operated the screw trap in the Breitenbush River above Detroit Reservoir from February 19 until December 9, 2016. The trap operated for 261 d and captured 1,290 subyearlings and two yearling Chinook salmon (Figure 8). The peak of migration was in

March - April (Figure 7) with a median migration date of March 24. Similar to other years when we operated a trap in the Breitenbush River (2011 and 2015), migration timing was earlier than the North Santiam River (Appendix B; Table B1). As noted in Romer et al. (2012), the difference in emergence timing between subbasins appears to be due to slightly warmer water in the Breitenbush River during the period of egg incubation. Most subyearlings (85% of our catch) entered Detroit Reservoir during March - May as fry averaging 35 mm FL (Figure 8). Few subyearlings (n=4) were caught in August-September, but low river flows prevented the trap from operating effectively. After flows increased in October-November, we caught 51 subyearlings.

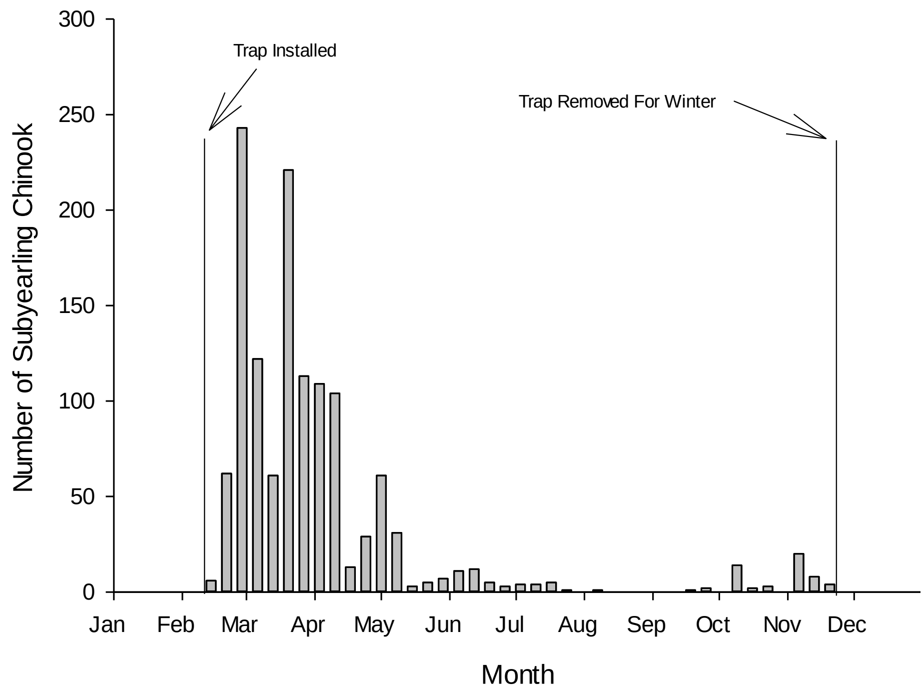

Figure 7. Weekly catch of subyearling spring Chinook salmon captured in the Breitenbush River trap above Detroit Reservoir, 2016.

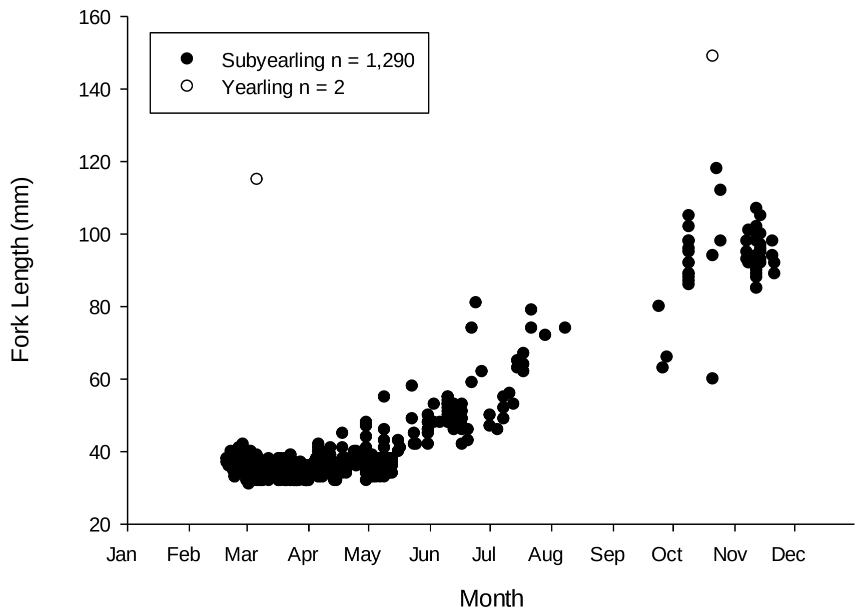

Figure 8. Fork lengths of juvenile Chinook salmon captured in the Breitenbush trap above Detroit Reservoir, 2016.

Below Big Cliff Dam- We continued operating 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 332 d in 2016 and captured 173 unmarked Chinook salmon, 17 hatchery Chinook salmon, and 255 kokanee.

The peak in passage of juvenile Chinook salmon exiting Big Cliff Dam occurred in June - September (Figure 9 and 10), in contrast to the peak of dam passage in November – December in 2015 and previous years. A large catch of fish occurred from June 13-24 comprised of hatchery yearlings (n=7) and unmarked yearlings (n=15), unmarked subyearlings (n=60), and kokanee (n=98) (Figure 10). Interestingly, many of the unmarked subyearlings (n=48) that passed during this period occurred during a brief period of from June 21-24. The unmarked subyearlings caught from July-September passed during a period of no spill. We were unable to operate the trap from mid to late October due to high spill discharge (Figure 9). Few fish were captured in November and December despite good trap operating conditions and spill from mid-November to mid-December.

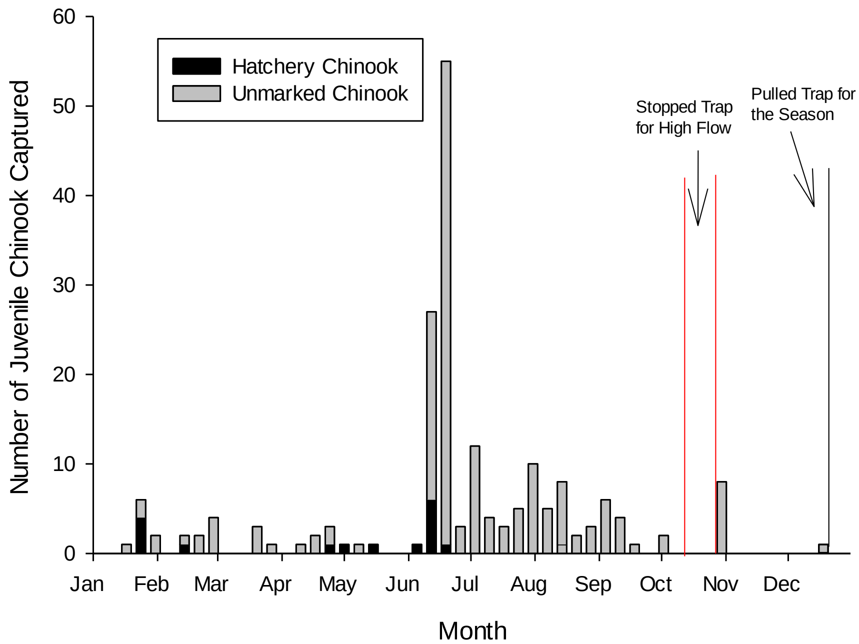

Figure 9. Weekly catch of marked and unmarked Chinook salmon (subyearling and yearlings) captured in the rotary screw trap below Big Cliff dam, 2016.

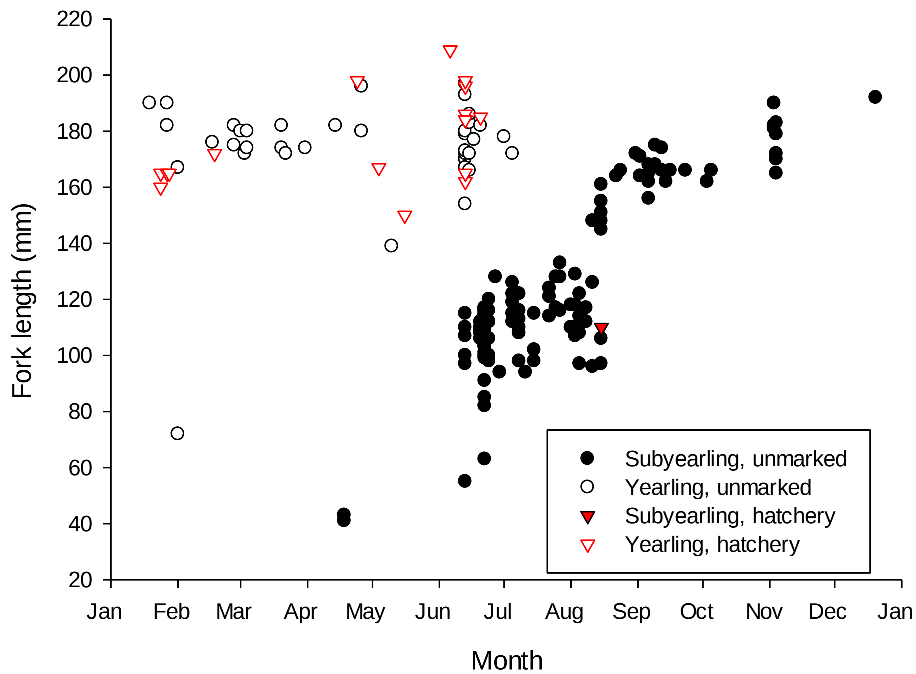

Figure 10. Fork lengths of juvenile Chinook salmon captured in the trap below Big Cliff Reservoir, 2016. Not shown was a 358 mm FL Chinook salmon caught on June 15.

South Santiam River Spring Chinook Salmon - We operated the South Santiam trap upstream of Foster Reservoir from January 1 through December 31, 2016. The trap did not operate from August 15 – September 1 because of high water temperatures (>18°C) that were beyond our take permit conditions and from December 4 – 16 due to high flows (Figure 11). The trap fished for 286 d in 2016 and captured 229 subyearlings and three yearlings. The trapped operated for a similar number of days as in 2015 but over four times as many subyearling Chinook salmon were collected in 2016, suggesting better juvenile production in 2016.

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. Similarly, the first fry from the 2014 BY were captured on December 18, 2014 (n = 12). The peak of migration was in January - March (Figure 11) with a median migration date of February 13. 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 12).

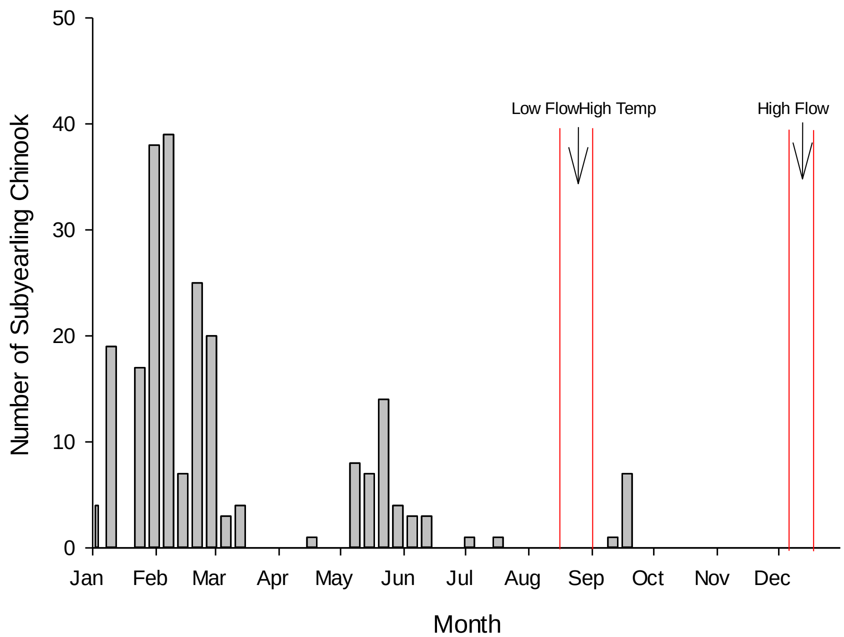

Figure 11. Weekly catch of subyearling spring Chinook salmon captured in the South Santiam trap above Foster Reservoir, 2016.

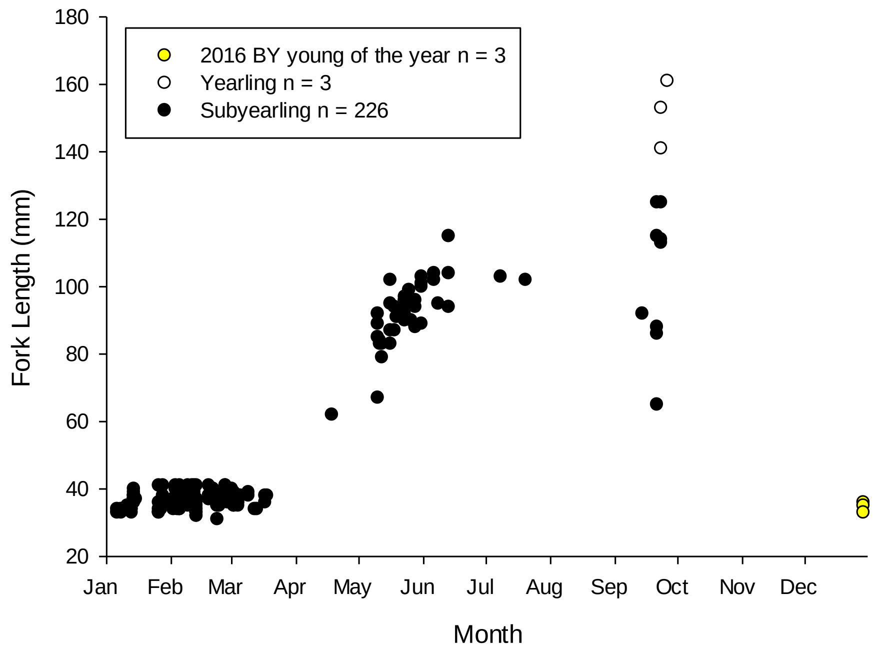

Figure 12. Fork length of subyearling and yearling Chinook salmon collected in the South Santiam trap above Foster Reservoir, 2016.

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 juvenile *O. mykiss* caught in the South Santiam trap upstream of Foster Reservoir is also usually an order of magnitude greater than in other basins where adult steelhead are not transported above dams. This assumption is further bolster by preliminary results of genetic pedigree analyses that indicated >94% of the juveniles captured in 2015 were progeny of outplanted adult steelhead (Chris Caudill, University of Idaho- personal communication). Suspected resident fish (>350 mm FL) were PIT tagged but not included in the following analyses.

The 581 juvenile *O. mykiss* captured in the South Santiam screw trap in 2016 was lower than 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 13). Most age-2 smolts and age-1 juveniles were caught in late April- early May and most age-0 juveniles were caught in July as recently-emerged fry (Figure 14). 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, similar to 2015 migration timing. In 2015 and 2016, the proportion of the annual catch comprised of age-1 and age-2 fish in the spring was atypically high compared to previous years (Figure 15).

Table 2. Catch of juvenile *O. mykiss* and days of trap operation at the South Santiam screw trap, 2010-2016.

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
2016	286	581

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

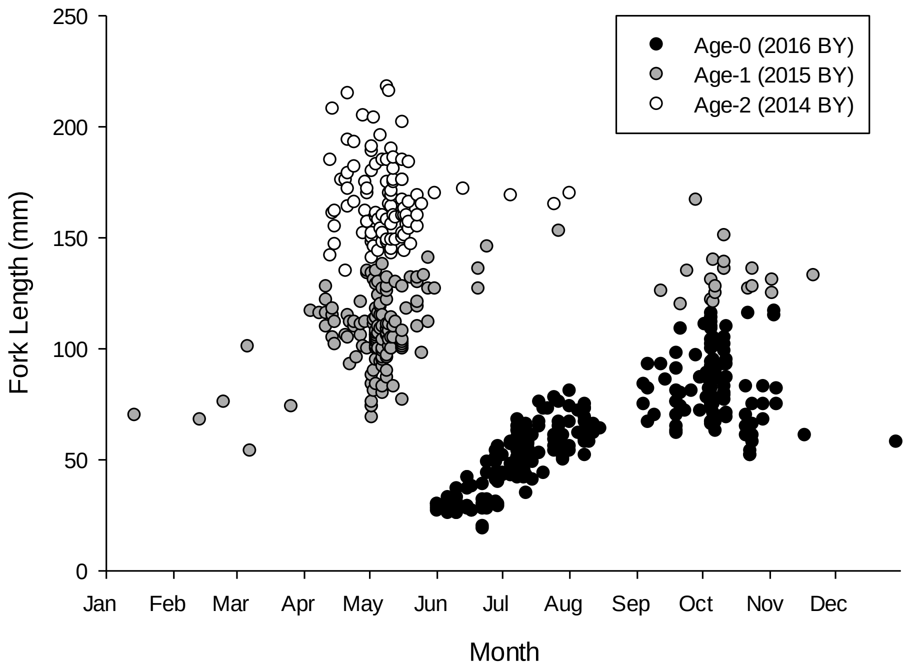

Figure 13. Fork lengths and estimated age of *O. mykiss* caught in the South Santiam trap above Foster Reservoir, 2016. One 300-mm FL *O. mykiss* was assumed to be a resident fish and was excluded from the graph. Age was estimated from length-frequency analysis. BY = brood year.

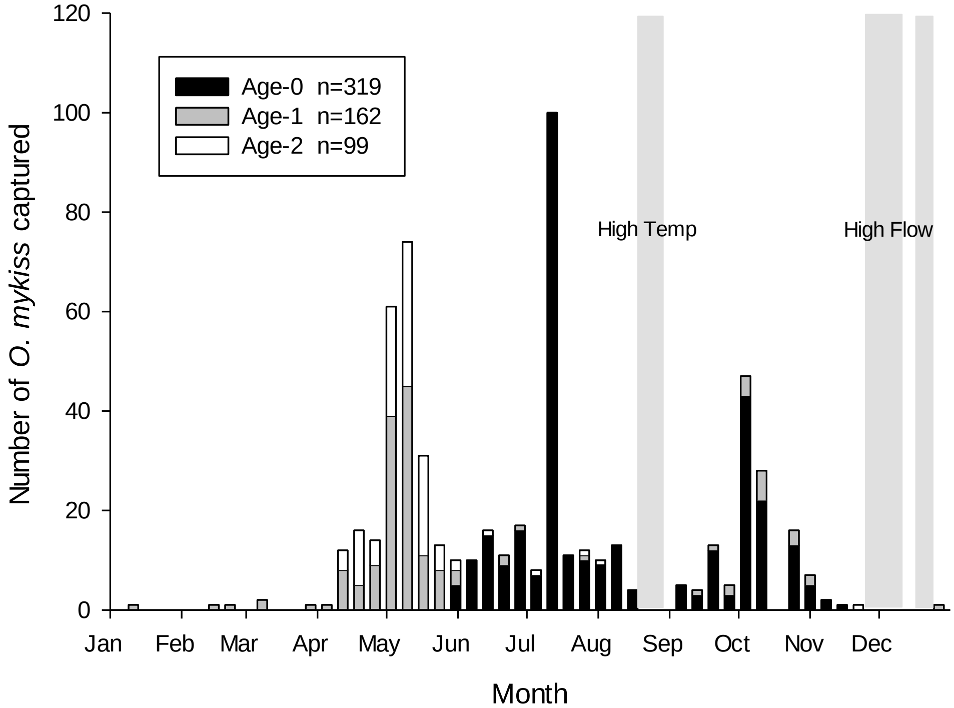

Figure 14. Weekly catch and estimated age of juvenile *O. mykiss* captured in the South Santiam trap above Foster Reservoir, 2016. Shaded areas indicate periods when trap was stopped due to either low flows and high temps (August) or high flows (December).

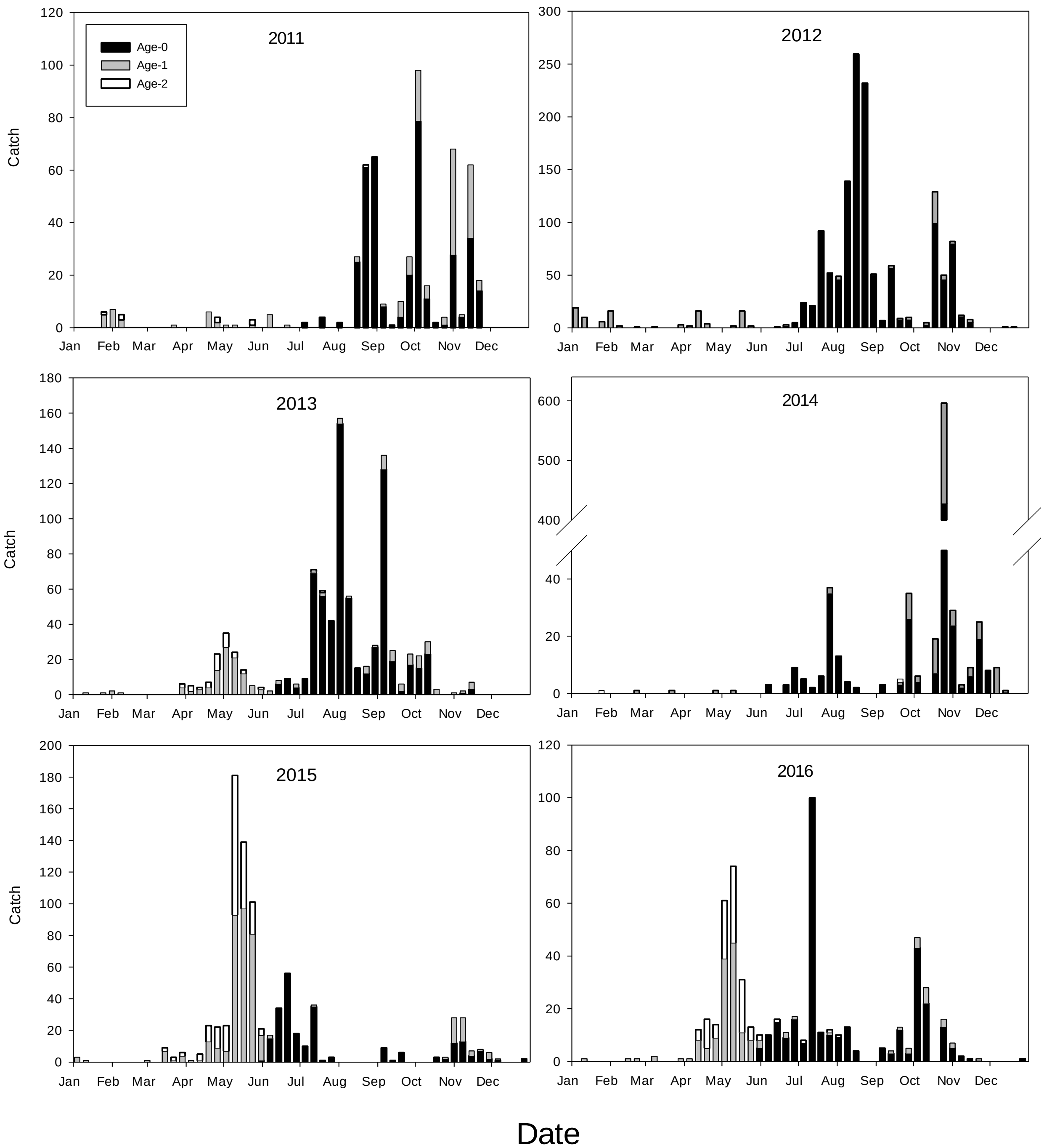

Figure 15. Number of *O. mykiss* captured in the South Santiam trap upstream of Foster Reservoir summarized by week for trapping seasons 2011-2016. Note different y-axis scales for each year.

Below Foster Dam - The 2.4-m screw trap below Foster Dam operated from January 1 – April 18, 2016 and ran for 107 d. The trap was decommissioned because we were unable to collect information from fish passage over the spillway for comparison, and because of complicated hydraulic conditions created by the turbine outflow resulting in low trap capture efficiency.

We captured 55 unmarked subyearling Chinook salmon (2015 BY) and two yearlings while the trap was operating (including nine fry from December 2015) (Figure 16). We initially installed the Foster Dam trap in 2011, and after five consecutive seasons of operation, it appeared that some subyearling Chinook salmon are able to pass through Foster Reservoir and dam to move into downstream rearing areas when the reservoir is at lower pool elevation and there is increased flow from the South Santiam River in winter. We captured the first 2015 BY Chinook salmon fry below Foster Dam on December 4, 2015. This emergence timing is similar to the previous brood year (2014 BY) but earlier than previous observations (Romer et al. 2015). It is possible that these fry were a result of spawning that occurred directly below the dam. The first fry from the same brood year were not captured upstream of Foster Reservoir until December 30, 2015. We did not catch any *O. mykiss* in the trap below Foster Dam in 2016 (Figure 17).

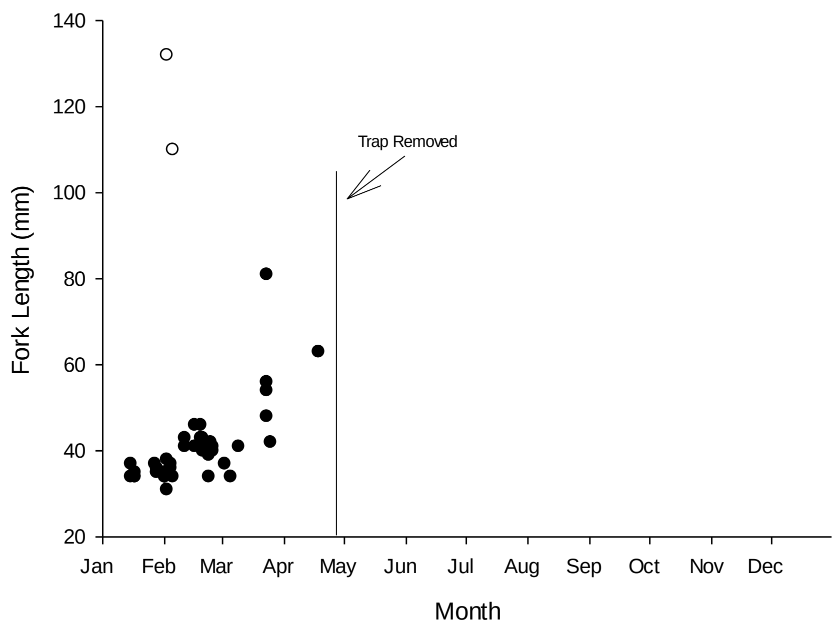

Figure 16. Fork lengths of unmarked juvenile spring Chinook salmon captured in the rotary screw trap below Foster Dam, 2016. Open circles denote yearlings. There were no *O. mykiss* captured below Foster Dam in 2016 during the time period when the trap was running.

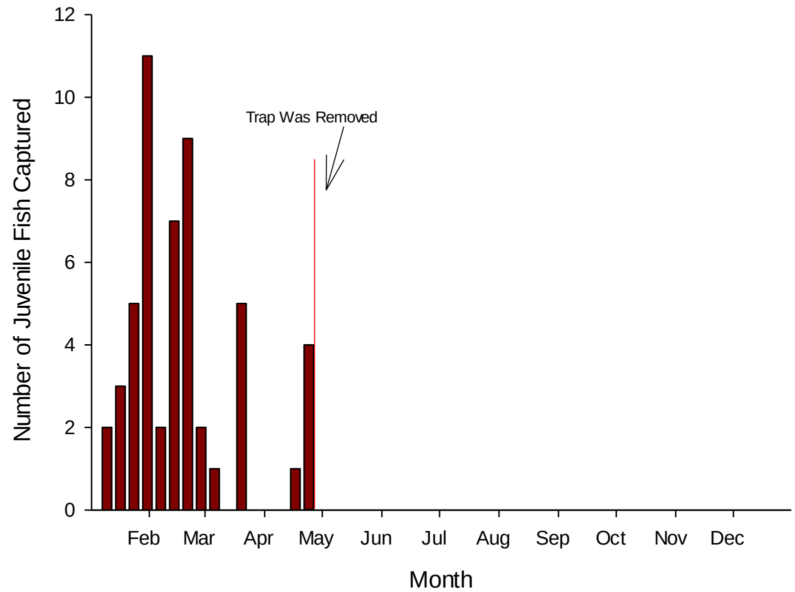

Figure 17. Weekly catch of unmarked Chinook salmon below Foster Dam, 2016.

North Fork Middle Fork Willamette River- We operated the North Fork Middle Fork (NFMF) Willamette River trap upstream of Lookout Point Reservoir from February 18 through December 21, 2016. The cone was raised and the trap was not operated when temperatures exceeded 18°C from August 18 until September 5. The peak of the Chinook salmon fry migration was March - April (Figure 18). The median migration date for all subyearlings was March 21 (Appendix B; Table B1). Although a smaller proportion of subyearlings migrated into Lookout Point Reservoir from September - December compared to 2015, it was still a relatively large proportion of subyearlings during this period (15.4%) relative to other traps (Table 3).

Fry are primarily carried by the current and are likely unable to avoid the screw trap, whereas subyearlings moving downstream in the late fall are larger (Figure 19), stronger swimmers and are likely able to avoid the trap, only getting captured during the best trapping conditions. This suggests that the proportion of fall migrants is likely much higher than reported in Table 3. We did not catch enough of fall migrants to make a good estimate of trap efficiency, and therefore abundance of these fall migrants is unknown. Even with this capture efficiency limitation, the consistently higher proportion of fall parr captured at the North Fork Middle Fork and North Santiam traps suggest these rivers hold more summer rearing habitat upstream of the reservoir relative to other sub-basins.

Table 3. Percent of juvenile Chinook salmon captured at trapping locations in the fall (September-December), 2013-2016, ranked from highest to lowest.

River	Year	Total Migrants	Sept – Dec Migrants	Percent
North Fork Middle Fork	2015	230	96	**41.7**
North Santiam	2013	305	74	24.3
North Santiam	2016	1,288	201	15.6
North Fork Middle Fork	2016	552	85	**15.4**
North Santiam	2015	1,646	118	7.2
South Santiam	2015	55	3	5.5
North Santiam	2014	1,151	60	5.2
South Santiam	2016	229	11	4.8
Breitenbush	2016	1,290	54	4.2
South Fork McKenzie	2015	4,996	169	3.4
South Fork McKenzie	2014	11,402	370	3.2
Middle Fork Willamette	2013	1,912	40	2.1
South Fork McKenzie	2013	20,082	327	1.6
South Santiam	2013	733	6	0.8
South Fork McKenzie	2016	21,169	127	0.6
Middle Fork Willamette	2014	1,342	5	0.4

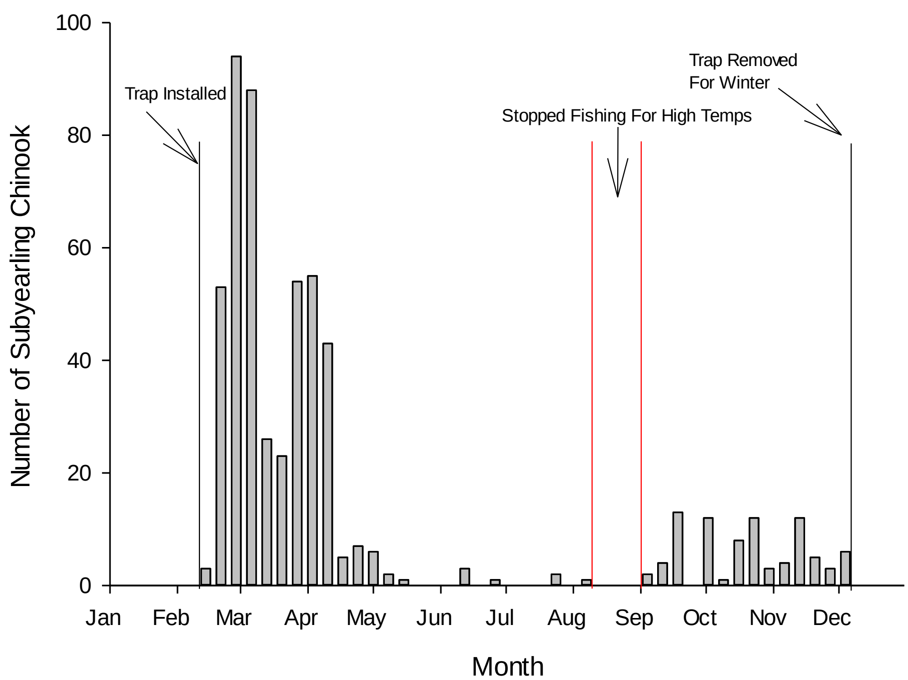

Figure 18. Weekly catch of subyearling spring Chinook salmon captured in the North Fork Middle Fork Willamette trap above Lookout Point Reservoir, 2016.

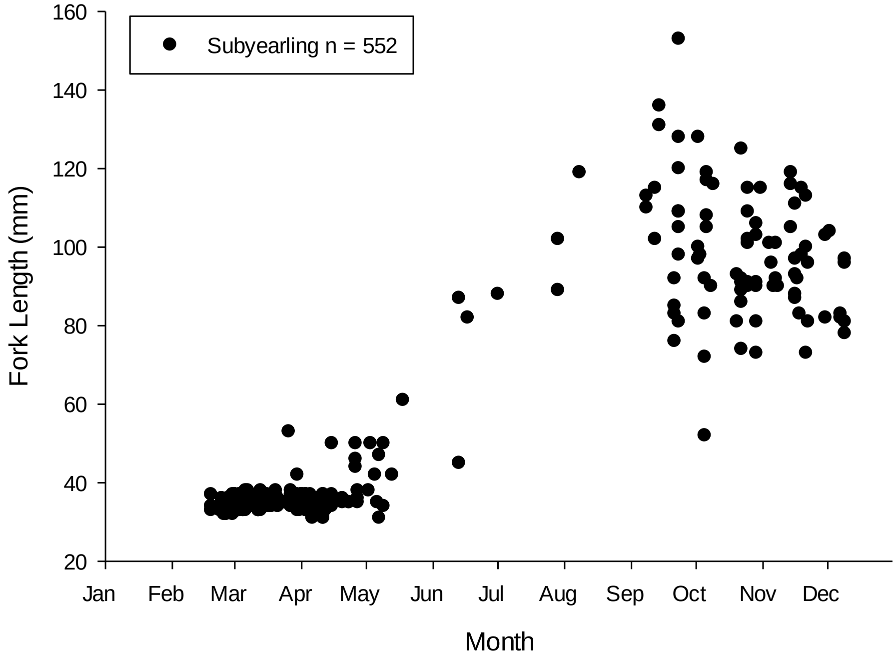

Figure 19. Fork lengths of juvenile Chinook salmon captured in the North Fork Middle Fork Willamette River trap above Lookout Point Reservoir, 2016.

Below Lookout Point Dam- The trap located below Lookout Point Dam was operated very infrequently by USACE personnel in 2016; we do not present those data here.

Below Fall Creek Dam- Historically, the USACE lowered the Fall Creek Reservoir pool level to a minimum elevation of 728 feet above mean sea level (msl) during the winter drawdown. This meant that juvenile fish exiting the reservoir had to sound at least 50 feet to reach the regulating outlets. In 2011 USACE implemented operations that lowered the reservoir to 680 feet above msl during the annual drawdown period to facilitate downstream juvenile Chinook salmon emigration from the reservoir. In 2016, the deep drawdown period occurred from November 3 –14.

Personnel from USACE operated a 2.4-m screw trap below Fall Creek Dam from January 4 to December 29, 2016. The trap operated 301 d but did not operate from November 3 – 26 due to high flows during reservoir drawdown. Following the completion of reservoir drawdown, the trap was restarted on November 28 and fished intermittently until December 29. The trap captured 103 unmarked subyearling Chinook salmon, all prior to the drawdown. The mean fork length of subyearlings leaving Fall Creek Reservoir by the beginning of November was 214 mm (n = 66; November 1-3). The trap also caught six 2016 BY fry from December 28-29, 2016. No yearling Chinook salmon were captured, as would be expected following the 2015 deep drawdown.

South Fork McKenzie River- We operated the South Fork McKenzie River trap upstream of Cougar Reservoir from February 29 to November 29, 2016 and fished the trap for 257 d. The first fry were captured on March 1 (n=27), 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 20), with a median subyearling migration date of April 13 (Appendix B; Table B1). This pattern was very similar to 2015 but early compared to previous years (2010-2014 range: April 26 – May 16). We have consistently observed a predominance of subyearlings migrating past our trap in early spring for the past six years, which is consistent with previous findings of other researchers (Bureau of Commercial Fisheries 1960; Monzyk et al. 2011; Zymonas et al. 2011; Romer et al. 2012, 2013, 2014, 2015, 2016). Overall, we collected 21,169 Chinook salmon subyearlings and 20 yearlings (Figure 21). Abundance estimates for subyearlings entering Cougar Reservoir in 2016 are presented in the *Abundance Estimates of Outmigrants* section below.

The size of subyearling Chinook salmon ranged from 30-97 mm FL, and the mean FL from March through May was 36 mm (n = 3,308, range 30-56 mm FL), approximately the size at which most would be expected to enter the reservoir. Very few yearlings were captured (n=20) (Figure 21).

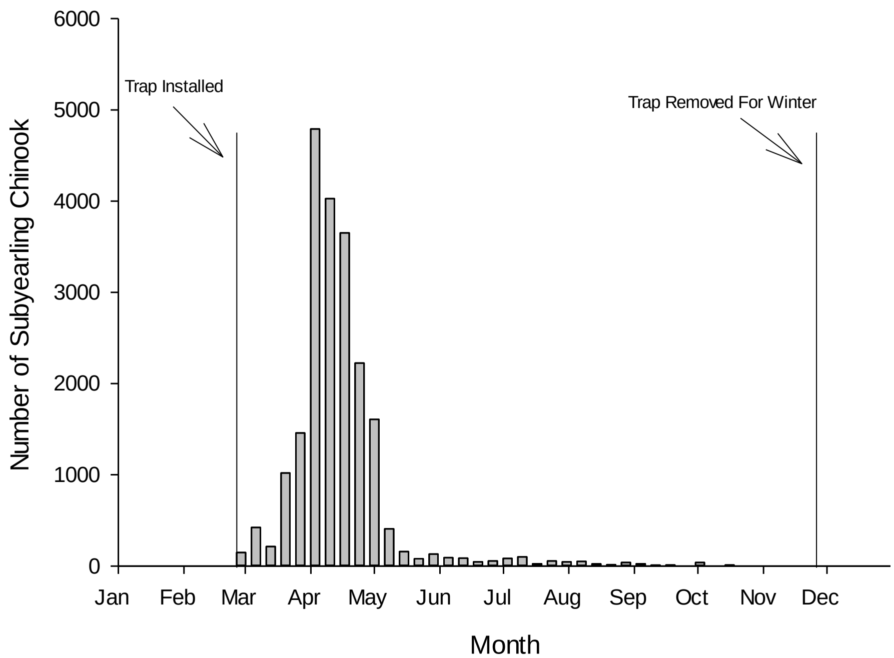

Figure 20. Weekly catch of subyearling spring Chinook salmon captured in the South Fork McKenzie River trap above Cougar Reservoir, 2016.

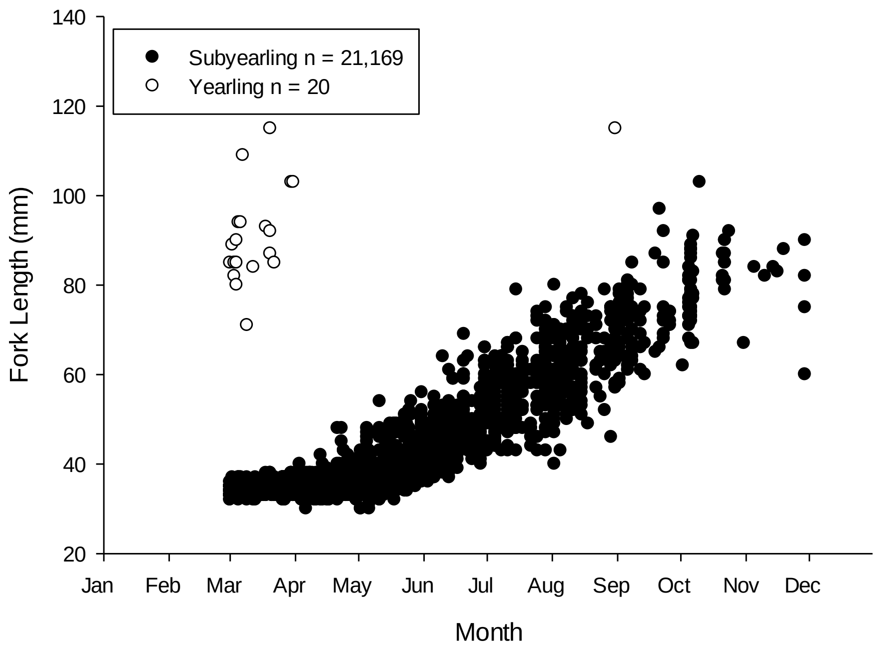

Figure 21. Fork length of subyearling and yearling Chinook salmon collected in the South Fork McKenzie River trap above Cougar Reservoir, 2016.

Below Cougar Dam – We operated three rotary screw traps below Cougar Dam in 2016. Trap operations were interrupted by unusual dam operations during the first part of the year. Repairs to a trash rack in the temperature control tower resulted in no flow through the turbines from December 15, 2015 – April 20, 2016. On March 3, 2016 the diversion tunnel (forebay opening @1325 ft msl) was opened to lower the reservoir elevation with the outflow passing into the turbine tailrace channel. Reservoir elevation was lowered to 1456 ft msl by March 26 and began to refill on March 31. The initial outflow from the tunnel on March 3 applied increased strain to the anchor point for the traps and pulled the concrete blocks out of position. We repositioned the anchor point and repaired the cables and deployed the traps successfully on March 29. From March 29 – April 20 we caught 51 subyearling Chinook (FL range: 32-38 mm) in the tailrace traps. These fish presumably passed the dam by sounding >131 ft. to exit through the diversion tunnel while the turbines were offline. No yearlings were caught in the tailrace traps until turbine flow resumed (Figure 22 and Figure 23).

The total trap catch from all traps below the dam for the year included 2,042 subyearling and 220 yearling unmarked Chinook salmon (Figure 23). Most (70%) subyearlings passed the dam in November and December, coinciding with lower reservoir pool elevations and increased discharge, primarily from the regulating outlet (Figure 22) consistent with 2015 observations (Romer et al. 2015).

The pattern of migration out of the reservoir in late fall (October-December) has been consistent over the years (Appendix C; Table C1). We have PIT-tagged many of the juvenile Chinook salmon that exited the reservoir (Appendix A; Table A2). Few of these fish were detected at Willamette Falls or downstream sites (Appendix A; Table A3). However, we note that among the detections of fish tagged in previous years from October-December, 10 of 11 (91%) were detected within 23 d of dam passage. This suggests not only that the majority of fish exited the dam in the fall, but most immediately migrated downstream to areas below Willamette Falls, presumably the Columbia Estuary.

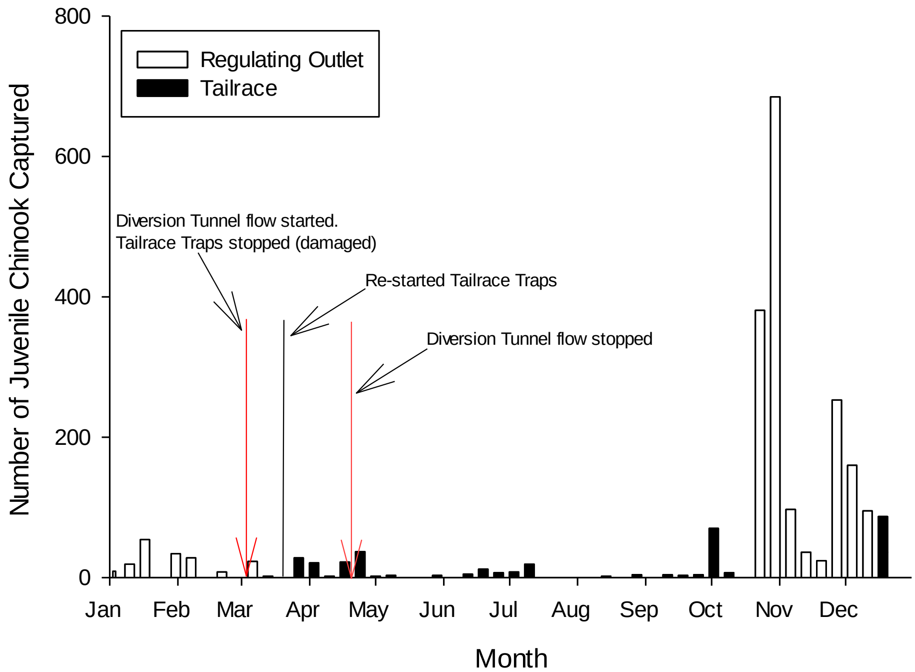

Figure 22. Weekly catch of unmarked juvenile spring Chinook salmon (subyearlings and yearlings) captured below Cougar Dam in rotary screw traps, 2016.

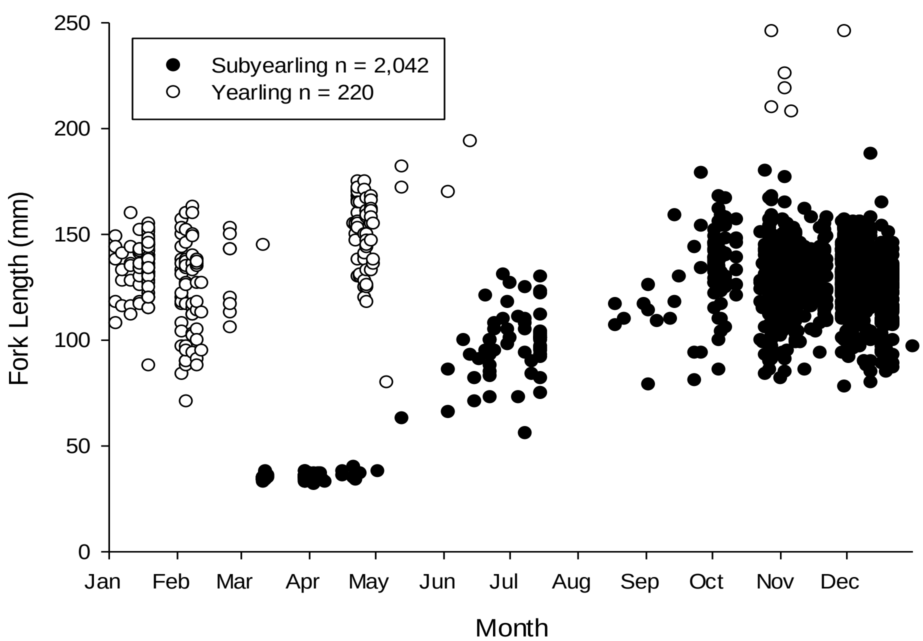

Figure 23 Fork length and capture date for natural-origin juvenile Chinook salmon captured below Cougar Dam, 2016.

Using data provided by USACE personnel from the portable floating fish collector (PFFC), we determined there was a delay in fall migrant dam passage timing under current dam operations. Beginning in September an increasing number of juvenile Chinook salmon were collected in the PFFC located in the forebay with a peak in October (Figure 24). Traps below the dam did not begin catching juveniles until the last week of October, associated with an increase in discharge from the regulating outlet (Figure 25). We concluded large numbers of juveniles were present in the forebay (available for dam passage) beginning in September but they did not start passing the dam until the last week in October.

Beckman and Dickhoff (1998) noted that Willamette subyearling Chinook salmon with rapid summer/fall growth had peak gill Na^{+} K^{+} ATPase activity in September-October, suggesting this may be a period of peak smolt migration. This smolting period coincided with peak catch in the PFFC. The large numbers of fish in the Cougar forebay in September-October agrees with results from Monzyk et al. (2015a) that showed subyearling Chinook salmon in Lookout Point Reservoir began congregating in the forebay by October, prior to major increases in reservoir inflows or outflows. It is possible that many of the rapidly growing subyearling Chinook salmon in reservoirs undergo smolt transformation in September-October but are unable to pass dams until outflows increase under current dam operations. More information on the smolting of reservoir-rearing Chinook salmon is needed to better match the biological timing of downstream migration to the operational timing of dam passage.

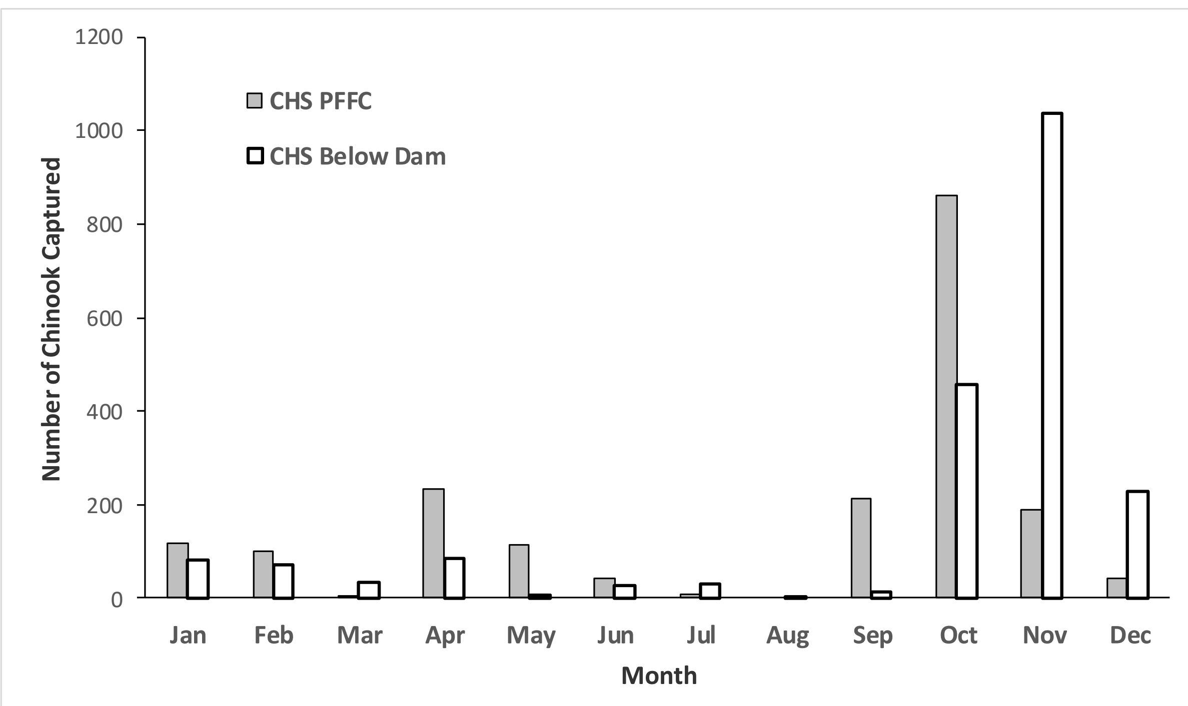

Figure 24. Monthly catch of juvenile spring Chinook salmon captured in the portable floating fish collector (PFFC) in the forebay of Cougar Reservoir and in screw traps below Cougar Dam, 2016.

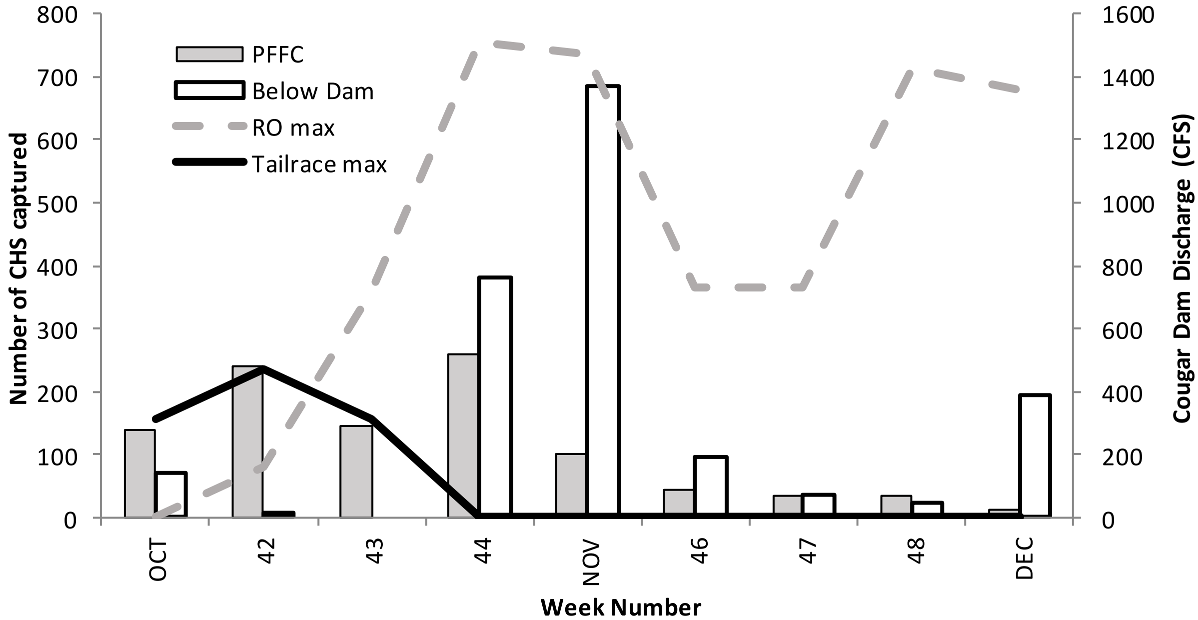

Figure 25. Weekly catch of juvenile spring Chinook salmon captured in the portable floating fish collector (PFFC) in the forebay of Cougar Reservoir and in screw traps below Cougar Dam from October to December, 2016, and maximum weekly dam discharge from turbines (tailrace) and regulating outlet (RO).

Abundance Estimates of Outmigrants

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 abundance estimate. Weekly trap efficiencies (TE) ranged from 2.4% to 13.3% with a weighted annual TE of 3.4% for 2016. Trap efficiency recapture numbers from mid-March through mid-May where robust and did not require pooling of weeks to estimate efficiency. This period also corresponded to the peak in fry movement past the trap.

We estimated that 627,876 (95% CI ± 98,638) subyearlings (2015 BY) migrated past the screw trap and into Cougar Reservoir between January and December 2016 (Table 4). This was the second highest juvenile production estimate since the onset of trapping at this location in 2010. Most (96%) subyearlings moved into Cougar Reservoir as fry from March through May. Once the fry had emerged, slight changes in weekly stream flow corresponded to changes in fry captured in the trap (Figure 26).

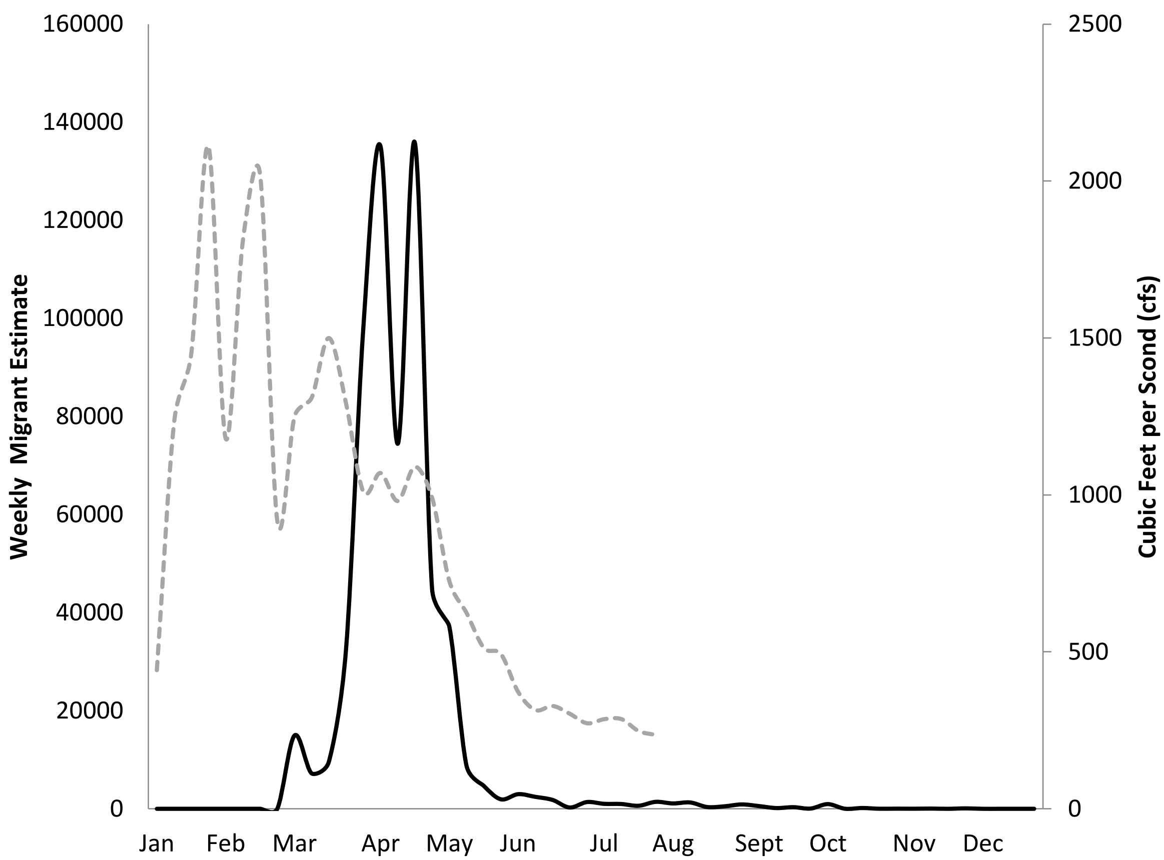

Figure 26. The estimated number of subyearling spring Chinook salmon migrating past the South Fork McKenzie trap and maximum weekly flow, 2016. The estimated number of fish is represented by the solid black line and corresponding flow is represented by the dotted grey line (USGS gauging station 14159200 near Rainbow).

Table 4. 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. (in prep).

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	0
2015	627,876	±98,638	456	137	21

[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 the trap were not surveyed.

Conclusions

Our trapping efforts demonstrated that juvenile Chinook salmon primarily migrate out of above-dam spawning areas as fry in early spring. Prior to dam construction, these fry would have continued dispersing to downstream rearing areas throughout the Willamette Basin, similar to fry emigration observed in unimpounded tributaries of the McKenzie River. With the development of the WVP Project, fry now rear for several months in reservoirs before continuing their downstream migration in the fall. Based on just one year of data comparing catch rates in the PFFC and traps below Cougar Dam, it appeared subyearlings are present in the reservoir forebay and available for passage for up to a month prior to when they actually pass the dam.

Long-term Chinook salmon migration trends in the NFMF (2015, 2016) and Middle Fork Willamette above Hills Creek Reservoir (2015) are not possible to discern since we have limited years of trapping in these locations. We 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 and trap sites that could explain why more fish appeared to rear for a longer period in the streams. Additional years of trap operations at these sites could help discern migration trends.

Juvenile steelhead in the South Santiam River demonstrated considerable variability in the age at which they entered Foster Reservoir. While in most years age-0 steelhead comprise the majority of fish caught in our trap, in 2015 and 2016 age-1 and age-2 fish were caught in relatively high numbers. The cause of this interannual variability in age of outmigration is uncertain. We do not have information on the interannual variability in location of steelhead redds (e.g., mainstem vs tributaries), but one possibility may be that in years when the majority of spawning occurs in the mainstem, more age-0 fry are captured in the trap.

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 through WVP projects. 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. 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 help mitigate the potential risks of copepod infection and predation risks 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). Facilitated interim passage would also encourage the expression of the full suite of spring Chinook life-history strategies (Schroeder et al. 2015). We further suggest investigating the fall timing of smolting for reservoir-reared Chinook salmon to better understand the best operational window for dam passage during this season.

We suggest that 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 (Appendix B; Table B2). 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.

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 and exiting the reservoir from proposed reintroductions.

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 2016.

Location	Subyearling	Yearling	Total
South Fork McKenzie	200	17	217
Cougar Reservoir	0	0	0
Cougar Tailrace	900	23	923
Breitenbush River	36	1	37
North Santiam River	189	3	192
Detroit Reservoir	0	0	0
Big Cliff Tailrace	41	0	41
Middle Fork Willamette	0	0	0
NF Middle Fork Willamette	78	0	78
Lookout Point Reservoir	13	0	13
South Santiam River	49	0	49
Foster Reservoir	60	1	61
Foster Tailrace	0	2	2
Total	1,566	47	1,613

Table A2. Number of juvenile Chinook salmon PIT-tagged at screw traps and reservoirs, 2010-2016.

Location	2010	2011	2012	2013	2014	2015	2016	Total
South Fk. McKenzie R.	83	615	897	1,287	812	320	217	4,231
Cougar Reservoir	440	547	537	84	295	1	0	1,904
Cougar Tailrace	--	1,081	308	14	220	0	923	2,537
Breitenbush R.	8	111	--	--	--	0	37	156
North Santiam R.	231	184	25	76	159	158	192	1,025
Detroit Reservoir	--	58	--	--	--	--	--	58
Detroit Tailrace	--	66	7	3	--	--	--	76
Big Cliff Tailrace	--	--	--	--	9	12	41	62
Middle Fk. Willamette	76	36	36	148	--	--	--	296
NFMF Willamette	109	78	177	--	--	75	78	517
Lookout Point Res	83	72	1	5	1	0	13	175
South Santiam R.	67	1	12	45	40	12	49	226
Foster Reservoir	--	--	--	60	54	39	61	214
Foster Tailrace	--	2	4	25	45	2	2	80
Total	**1,097**	**2,842**	**2,004**	**1,747**	**1,635**	**619**	**1,613**	**11,557**

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	2016
North Santiam River	Big Cliff Tailrace	--	--	--	--	0	**1**	0
	Bennett	--	--	--	--	0	0	0
	Stayton	--	--	--	--	**1**	**2**	0
	Willamette Falls	**3**	**2**	0	0	0	**2**	0
	Columbia River Trawl	**1**	0	0	0	0	0	0
Breitenbush River	Willamette Falls	0	**2**	--	--	--	0	0
Detroit Reservoir	Willamette Falls	0	**1**	0	0	--	--	--
Detroit Tailrace	Willamette Falls	0	**1**	0	0	0	--	--
Big Cliff Tailrace	Bennett	--	--	--	--	--	**1**	0
	Stayton	--	--	--	--	--	**1**	**9**
South Santiam River	Foster Reservoir	--	--	--	0	**1**	0	0
	Foster Weir	--	--	--	--		0	0
	Lebanon Dam	--	--	--	--	--	0	**2**
	Willamette Falls	**4**	0	0	**2**	**3**	**2**	**1**
	Will. Falls ADULT	0	0	**1**	0	0	0	0
Foster Reservoir	Foster Weir	--	--	--	--	**1**	**2**	**3**
	Lebanon Dam	--	--	--	--	--	**8**	**6**
	Willamette Falls	--	--	--	**1**	0	**6**	**3**
Foster Tailrace	Willamette Falls	--	--	0	**4**	**6**	0	--
SF McKenzie River	Cougar Reservoir	0	**4**	0	0	0	0	0
	USACE Fish Collector	--	--	--	--	**4**	**5**	0
	Cougar Tailrace	0	**10**	**14**	**19**	**4**	0	0
	Leaburg	0	**15**	**23**	**53**	**18**	**5**	**4**
	Walterville	--	0	**19**	**18**	**6**	0	**2**
	Willamette R3 (175-301)	0	0	**1**	0	0	0	0
	Willamette Falls	0	**2**	**10**	**3**	**4**	0	0
	Columbia River Trawl	0	**1**	0	**2**	0	0	0
	Will. Falls ADULT	0	1	0	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**	**3**	0	0	--	--
Cougar Tailrace	Leaburg	0	**204**	**51**	**5**	**77**	--	**61**
	Walterville	0	**23**	**3**	**4**	**12**	--	**76**
	Willamette Falls	0	**12**	**4**	**1**	**3**	--	**3**
	Columbia River Trawl	0	**1**	0	0	0	--	0
	East Sand Island	0	0	**1**	0	0	--	0
	Will. Falls ADULT	0	**1**	**1**	0	0	--	0

Table A3 continued.

Tagging Location	Recap/Interrogation Location (RKM)	Number Recaptured 2010	2011	2012	2013	2014	2015	2016
	Cougar Trap & Haul	0	**1**	0	0	0	--	0
NFMF Willamette River	Willamette Falls	--	**1**	**2**	--	--	**2**	0
	Columbia River Trawl	--	0	**1**	--	--	0	0
	Will. Falls ADULT	--	**1**	0	--	--	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	--	--	0
	East Sand Island	0	0	0	0	--	--	0

Appendix B. Basin-wide information.

Table B1. Median migration date by year for subyearling Chinook salmon migrating past screw trap sites, 2010-2016.

	Median Migration Date						
Location	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
North Santiam	--	May 6	May 14	May 14	May 8	Apr 20	Apr 27
Breitenbush	--	Mar 8	--	--	--	Mar 27	Mar 24
South Santiam	--	--	Mar 7	Feb 28	--[a]	Jan 30	Feb 13
South Fk McKenzie	May 1	May 16	May 16	Apr 26	May 8	Apr 9	Apr 13
Middle Fk Willamette (above Hills Cr. Res.)	--	--	--	--	--	Mar 29	--
North Fk Middle Fk	--	--	--	--	--	May 16	Mar 21
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 B2. 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 2010-2015.

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
	2015	627,876	±98,638
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%)

Appendix C. Long-term screw trap catch information.

Table C1. Number of juvenile Chinook salmon captured each month below Cougar Dam partitioned by brood year (2009-2015). Data are summarized on a 24-month scale corresponding to the typical reservoir exit timing for the entire cohort. Monthly catch is total from all traps below dam. Asterisks denote the last available month of data collection.

Life Stage	Month	2009 BY	2010 BY	2011 BY	2012 BY	2013 BY	2014 BY	2015 BY
Fry (< 60 mm)	Jan	0	0	0	0	0	6	0
Fry (< 60 mm)	Feb	0	0	0	0	24	17	0
Fry (< 60 mm)	Mar	0	13	6	0	26	118	47
Fry (< 60 mm)	Apr	9	1	6	118	18	186	33
Fry (< 60 mm)	May	1	1	23	60	15	8	2
Fry/Subyearling	Jun	127	9	25	218	34	9	22
Fry/Subyearling	Jul	0	17	12	20	9	0	29
Fry/Subyearling	Aug	80	38	380	31	4	1	4
Subyearling	Sep	26	19	60	60	1	2	15
Subyearling	Oct	60	90	250	940	137	61	455
Subyearling	Nov	905	942	1,068	2,605	3,113	326	1,033
Subyearling	Dec	2,155	125	1,174	272	242	525	402*
Yearling	Jan	373	288	6	46	15	82	
Yearling	Feb	72	4	2	95	29	70	
Yearling	Mar	62	12	2	217	3	1	
Yearling	Apr	242	82	35	191	4	54	
Yearling	May	153	20	96	73	2	3	
Yearling	Jun	48	5	26	3	0	4	
Yearling	Jul	10	0	0	1	0	0	
Yearling	Aug	0	0	0	0	0	0	
Yearling	Sep	1	0	0	0	0	0	
Yearling	Oct	0	2	15	2	2	3	
Yearling	Nov	17	13	62	24	5	3	
Yearling	Dec	2	6	0	3	1	0	
	Total	4,343	1,687	3,248	4,979	3,684	1,479	2,042

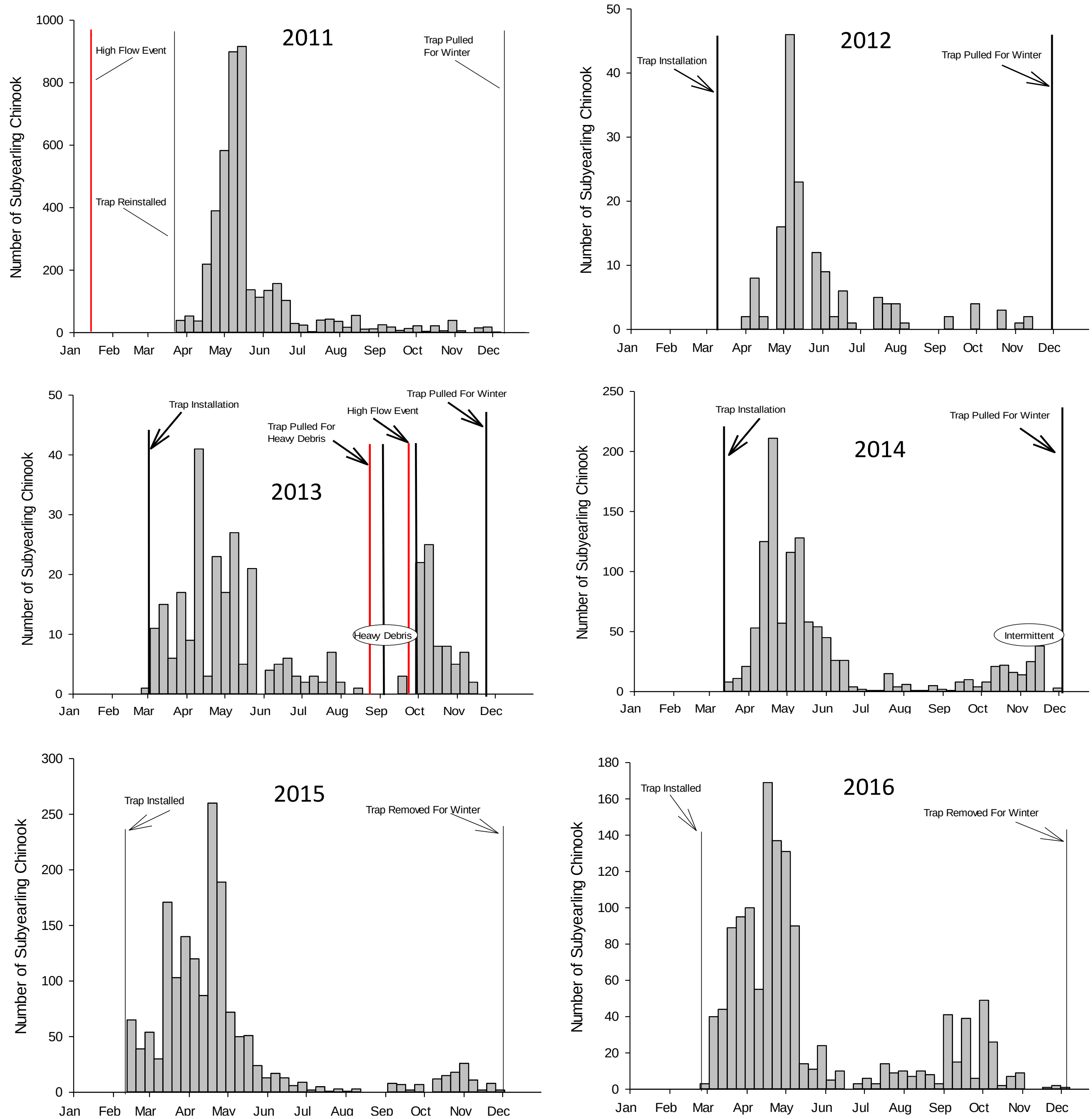

Figure C1. Migration timing of juvenile Chinook salmon caught in the rotary screw traps located in the North Santiam River upstream of Detroit Dam, 2011-2016.