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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 research and monitoring data that can be used to evaluate options for development of downstream passage for juvenile salmonids *Oncorhynchus* spp. at upper Willamette reservoirs. We present data from screw trap operations above and below USACE project dams during 2013. Traps upstream of reservoirs were located on the North Santiam River above Detroit Reservoir, the South Santiam River above Foster Reservoir, the South Fork McKenzie River above Cougar Reservoir, and the Middle Fork Willamette River above Lookout Point Reservoir. Traps were also located below Detroit, Foster, Cougar, and Lookout Point dams (Figure 2).

The objectives of this project were 1) to provide information on migration timing of juvenile spring Chinook salmon *O. tshawytscha* and winter steelhead *O. mykiss* into Willamette Valley Project (WVP) reservoirs; 2) to provide information on emigration timing of juvenile salmonids out of the reservoirs; 3) determine size at which juveniles enter and exit the reservoirs, and 4) estimate the abundance of juvenile Chinook salmon entering reservoirs where trap efficiency (TE) criterion were met. This information will be used to inform management decisions regarding fish passage alternatives and to help gauge the success of the current adult outplanting program.

In 2013, 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 in accordance with emergence timing of Chinook salmon observed in previous sampling years. All upstream traps were removed from service for a period near the end of September (near the peak of the adult spawning season) due to heavy rain and high river levels throughout the upper Willamette Basin. Traps were operated throughout the calendar year until removal in mid-late November in anticipation of high stream flows. The majority of juvenile spring Chinook salmon entered WVP reservoirs as fry (< 60 mm fork length) in early spring, soon after emergence. This suggests that prior to dam construction, these Chinook fry may have continued dispersing downstream throughout the Willamette Basin – similar to fry emigration observed in unimpounded tributaries of the McKenzie River. Yearling age-class Chinook salmon entering reservoirs were rare, and yearlings were generally collected in late winter and early spring upstream of reservoirs.

Chinook salmon fry typically entered WVP reservoirs from February through June. River flow levels, incubation temperatures, distance from spawning areas to reservoirs, and quality of upstream rearing habitats can affect reservoir entry timing and size of juvenile Chinook salmon. The peak months of reservoir entry for subyearlings that outmigrate from the North Santiam River were April and May, with a median migration date of May 14. In the South Santiam River above Foster Reservoir the median migration date was February 28, two months earlier than the South Fork McKenzie and North Santiam rivers. Similar to the North Santiam population, the peak downstream movement of subyearlings in the South Fork McKenzie River was April – May, with a median migration date of April 26, about two weeks earlier than in 2012. Peak movement of subyearlings in the Middle Fork Willamette River and reservoir entry into Lookout Point Reservoir was February – June, with a median date of April 4.

The average fork length (FL) of fry entering most WVP reservoirs in the spring was 35 mm. Subyearling migrants captured in most upstream traps were ~35 mm until June except migrants collected at the Middle Fork Willamette and South Santiam traps, which exhibited a relatively large variation in size as they entered Lookout Point and Foster reservoirs, respectively. We suspect the larger variation in size for the Middle Fork Willamette and South Santiam migrants was partly due to the greater extent of rearing habitat between spawning areas and our trap in the Middle Fork Willamette and earlier emergence and higher water temperatures in the South Santiam. This was the first year since 2010 (2009 brood year) that we have captured juvenile Chinook in the South Santiam throughout the trapping season. All juvenile Chinook salmon collected in upstream traps and *O. mykiss* in the South Santiam River > 65 mm FL were tagged with passive integrated transponder (PIT) tags to collect migration and growth information upon recapture or detection at downstream antenna arrays.

Data collected from trapping below dams indicated that typically, very few Chinook salmon fry continued migration through the reservoirs in the spring. We captured few fry in traps below Cougar and Lookout Point dams in 2013. However, most Chinook were caught as fry below Foster Dam, suggesting that some fry were able to successfully pass the reservoir and dam. Most juvenile spring Chinook salmon exit WVP reservoirs as subyearlings in late fall/winter (October – February), in conjunction with reservoir drawdown and lowered pool elevation. In Lookout Point and Detroit reservoirs, several juvenile Chinook salmon were also captured between May and June during spill operations, consistent with our 2012 observations.

In this report we use ‘flow’ to describe water movement upstream of dams where flow is naturally affected by environmental factors (i.e. snow melt, precipitation). We refer to water movement below dams as ‘discharge’ where it is regulated by dam operations. Precipitation and corresponding flow levels were low and less stochastic throughout 2013 compared to the last two sampling seasons, with the exception of an abnormally wet September. September precipitation included a very heavy rain event on September 30, during the peak of the adult Chinook salmon spawning season (Appendix B; Figure B1). Less rain and fewer stochastic flow events resulted in more days of uninterrupted trap operations for most of our screw traps.

The South Santiam River above Foster Dam is currently the only reach above a WVP reservoir with winter steelhead production. Juvenile *O. mykiss* (presumably winter steelhead) were captured in the South Santiam screw trap throughout the year with the greatest catch occurring from July through November. Subyearling *O. mykiss* emerged and began moving downstream near the end of June and reached a maximum size of ~100 mm FL by the end of December. We captured 865 juvenile *O. mykiss* and PIT-tagged 361 upstream of Foster Reservoir in 2013. More age-2 *O. mykiss* were captured moving downstream than in previous years and 91% of these fish passed the trap in April-May, consistent with expected smolt outmigration timing. Age estimates were based on differences in fork length among cohorts.

The 2012 brood year (BY) of spring Chinook salmon in the South Fork McKenzie was the largest since the 2009 BY. The number of subyearlings moving past our trap into Cougar Reservoir was estimated based on trap efficiency (TE) estimates ranging from 1.7 to 17.6%, and a yearly weighted TE of 3.8%. For all other upstream traps, TE was low or too few juveniles were captured to accurately calculate point estimates for the number of fish migrating past our traps. In the South Fork McKenzie we captured 20,082 Chinook salmon subyearlings, and estimated 557,526 (95% CI ± 66,031) subyearlings migrated past our trap. In 2013 the majority (92%) of subyearlings moved into Cougar Reservoir as fry from March - May.

The abundance of live juvenile Chinook salmon exiting Cougar Dam from the 2012 brood year was estimated based on screw trapping information collected below the dam. Weekly trap efficiencies ranged from 2.8 to 17.1% with a weighted annual TE of 4.9% for the turbine outflow, and 3.0 to 4.5% with a weighted annual TE of 3.7% for the trap in the regulating outlet. We estimated that 55,335 (95% CI ± 11,879) live subyearling Chinook salmon exited Cougar dam through the turbines, and 32,370 (95% CI ± 22,285) passed through the regulating outlet in 2013. Using the 2013 weighted yearly trap efficiencies for each of the routes and catch information through April 23, 2014, we estimated that an additional 5,526 (95% CI ± 1,345) yearlings from the 2012 BY exited through the turbines, and 3,433 (95% CI ± 2,564) from the regulating outlet in spring 2014. Using these estimates, ~17% (11.4 – 24.8%) of Chinook salmon subyearlings migrating past the screw trap upstream of Cougar Reservoir in 2013 (2012 BY) survived to below Cougar Dam.

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

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

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

This report fulfills a requirement under Cooperative Agreement Number W9127N-10-2-0008-0019, for outmigration monitoring from April 2013–March 2014. Data in this report includes summary and analysis of field activities implemented by ODFW on behalf of the USACE through December 31, 2013 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 2013 were located on the North Santiam River upstream of Detroit Reservoir, the South Santiam River upstream of Foster Reservoir, the South Fork McKenzie River upstream of Cougar Reservoir, and the Middle Fork Willamette River upstream of Lookout Point Reservoir (Figure 2). All rotary screw traps above project reservoirs were 1.5 m diameter, and trapping sites remained consistent with 2012 sampling locations (Table 1; Romer et al. 2013), with the exception of the trap in the Breitenbush River upstream of Detroit Reservoir. The Breitenbush trap was not deployed because only two redds were observed during 2012 spawning ground surveys (Sharpe et al. 2014). Deployment date for each trap varied by basin in accordance with expected emergence timing based on observations in previous sampling years (Monzyk et al. 2011; Romer et al. 2012, 2013). Traps remained fishing throughout the calendar year until removal in mid-late November in anticipation of high stream flows. The exception was the trap in the South Santiam, which was kept in place throughout the calendar year. All upstream traps were removed from service for multiple days near the end of September (near the peak of the adult spawning season) due to heavy rain and associated high river levels throughout the upper Willamette Basin (Appendix B; Figure B1).

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 Middle Fork Willamette trap was located downstream of the town of Westfir, near the USFS seed orchard, ~5 km upstream of Lookout Point Reservoir (at full pool).

Below Project Traps- We continued trapping efforts in 2013 below Detroit, Foster and Cougar dams. We also received and summarized migrant data from the 2.4-m trap operated by the USACE below Lookout Point Dam (Figure 2). Controlled discharge from the dam allows us to fish these traps nearly every day of the year excluding events such as extremely high dam discharge, maintenance, safety upgrades, debris or substrate movement preventing the trap from spinning (e.g., 2013 tailrace trap).

We operated two traps below Detroit Dam. We continued operation of our 1.5-m trap located 579 m downstream of the dam at the edge of the boat restricted zone (BRZ) until November 2013. This trap allowed us to capture fish exiting through all possible dam passage routes (turbines, spillways, and regulating outlets). However, repairs on Big Cliff Dam spillway gates in November enabled USACE to bring Big Cliff Reservoir to full capacity, inundating our trapping site. In anticipation of this, we placed a 2.4 m trap near the turbine tailrace of Detroit Dam in March. Operation of both traps overlapped from March-November.

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, which enabled us to differentiate catch between the two routes (two 2.4-m diameter traps in the turbine tailrace, one 1.5-m diameter trap in the regulating outlet). Typically, the two traps in the tailrace operate side by side (Figure 1). From May 28 – October 14 the stream depth was too shallow to operate the trap farthest from shore. This trap operated 213 d while the near-shore trap operated 354 d (Figure 4).

Figure 1. Turbine tailrace rotary screw traps (2.4 m diameter; rkm 385) below Cougar Dam.

Below Foster Dam, the 2.4-m diameter trap was in the tailrace of the turbine discharge and did not capture fish exiting the reservoir via the spillways. The 2.4-m trap located below Lookout Point Dam was operated by USACE personnel and was located ~260 m downstream of the base of the dam.

Table 1. Installation dates and location of rotary screw traps above and below Willamette Valley Project reservoirs, 2013. River kilometer (rkm) refers to the distance from the specified location to the confluence with the Columbia River. BRZ = Boat Restricted Zone. UTM coordinates expressed as NAD 83 datum.

Trap Location	Installation Date	rkm	UTM (10T)
	Upstream of Reservoirs		
Breitenbush	None[a]	286	0568785 4955753
North Santiam	March 8	292	0575240 4949260
South Santiam	January 7	271	0539897 4915479
South Fork McKenzie	February 28	395	0562654 4877522
Middle Fork Willamette	February 12	358	0537699 4846035
	Below Dams		
Detroit – BRZ bridge	January 1	271	0558956 4952722
Detroit – Turbine tailrace	March 12	271	0559186 4952388
Foster	January 2	253	0526128 4917989
Cougar	January 1	385	0560486 4886873
Lookout Point	January 1	333	0519724 4862480

[a] Trap not deployed in 2013; no adult fish were outplanted in the Breitenbush River in 2011 or 2012.

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 upon 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. Fish numbers reported for trapping reflects actual catch and were not adjusted for TE or days when the trap was not operated, unless otherwise stated. The South Santiam trap (above Foster Dam) was below most major spawning habitat for adult winter steelhead, which facilitated collection of migration data for juvenile steelhead and spring Chinook salmon.

Fish captured in traps were removed, identified to species, anesthetized with MS-222, and counted. Age class of Chinook salmon (subyearling or yearling) was determined 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" (as defined above; minimum 25 per day) and released all fish ~100 m downstream of the trapping site, except for those retained for trap capture efficiency estimates.

Age estimates of measured juvenile Chinook salmon were verified with length-frequency analysis. Yearling and subyearling Chinook salmon had bimodal size distributions with minimal overlap throughout the year. We graphed individual fish size by date and age estimate for each trap. Juveniles that hatched in spring 2013 (2012 BY) were classified as subyearlings, and yearlings were fish that hatched the previous year (2011 BY) and remained in the reservoir after January 1, 2013. Previously we have considered salmonids < 50 mm FL as fry. This year, to maintain consistency with other projects in the basin, we now consider salmonids **< 60** mm as fry. We report outmigration timing during the calendar year (January - December). Therefore, yearlings and subyearlings comprise different cohorts.

Juvenile Chinook salmon and winter steelhead > 65 mm FL were tagged with passive integrated transponder (PIT) tags (Appendix A; Table A1; A2; A3) to collect recapture and detection information (Appendix A; Table A4) regarding growth and migration behavior. Growth information can be found in Monzyk et al. (2014).

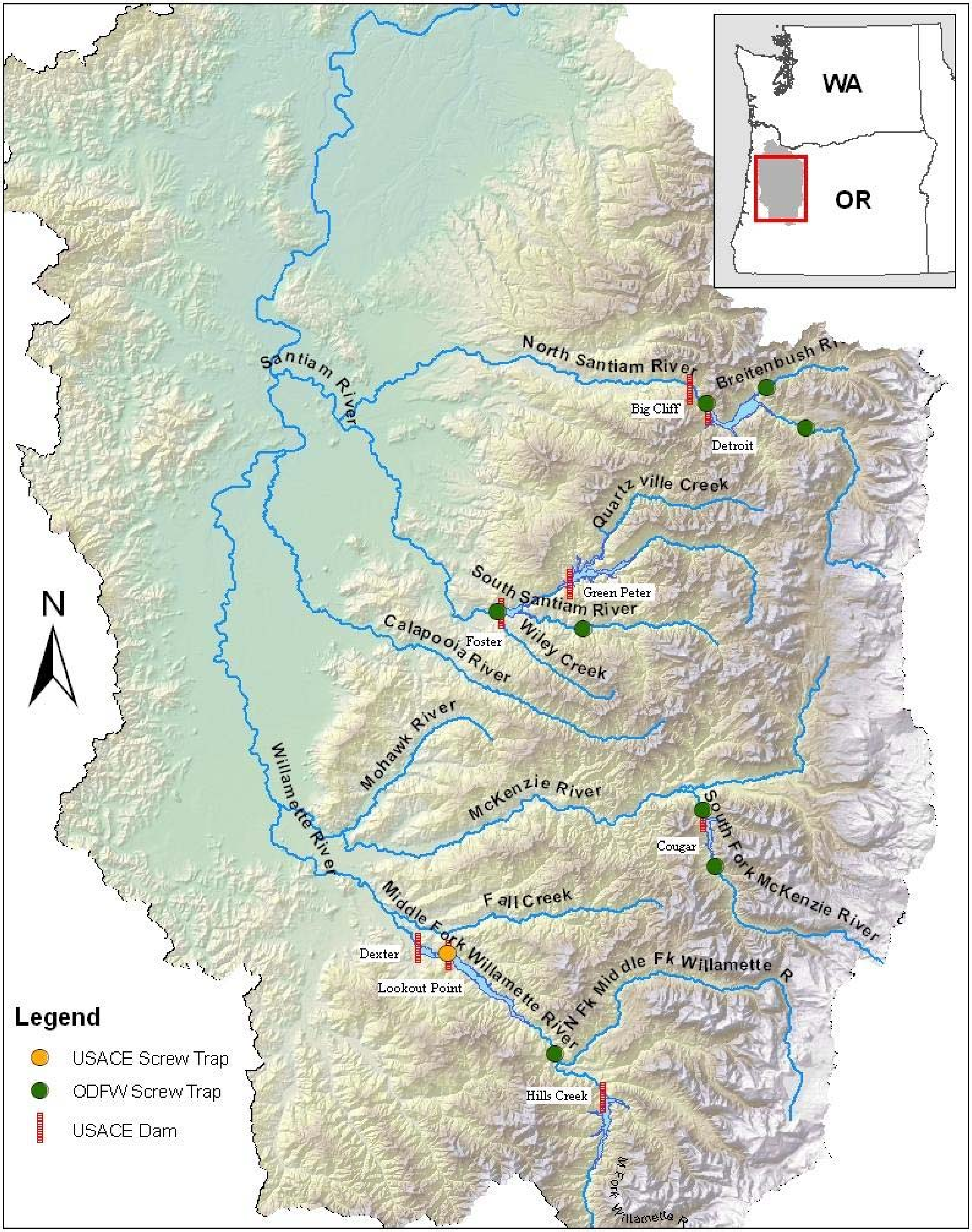

Figure 2. Locations of rotary screw traps operated by the Oregon Department of Fish and Wildlife (ODFW) and USACE above and below Willamette Valley Project dams. The Breitenbush River trap was not operated in 2013.

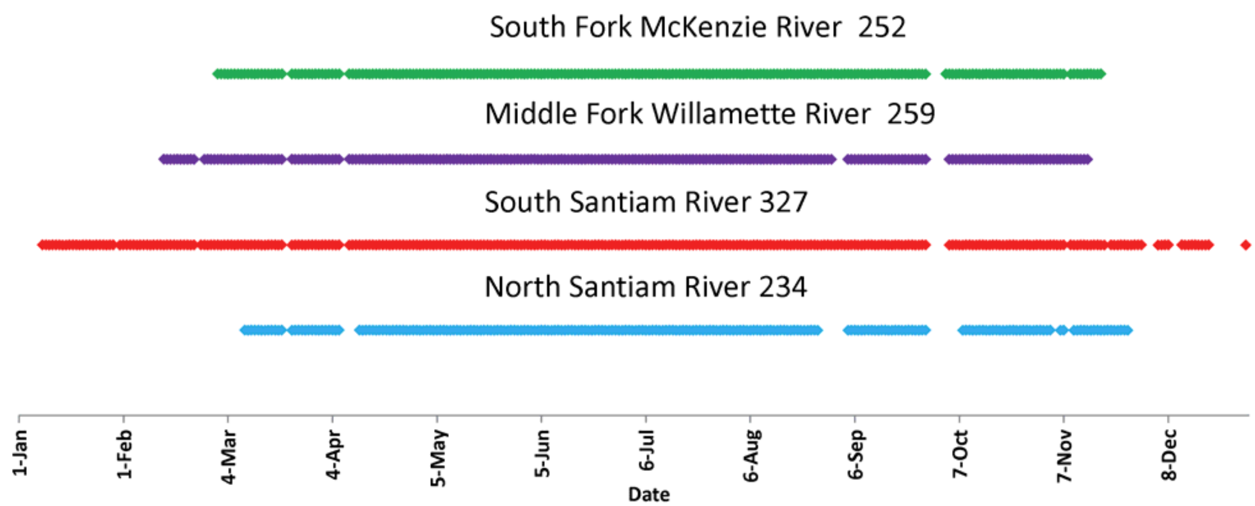

Figure 3. Screw trap operation summary for traps upstream of Willamette Valley reservoirs, 2013. Each colored dot represents one day of operation; numbers are the number of days the trap operated during the calendar year.

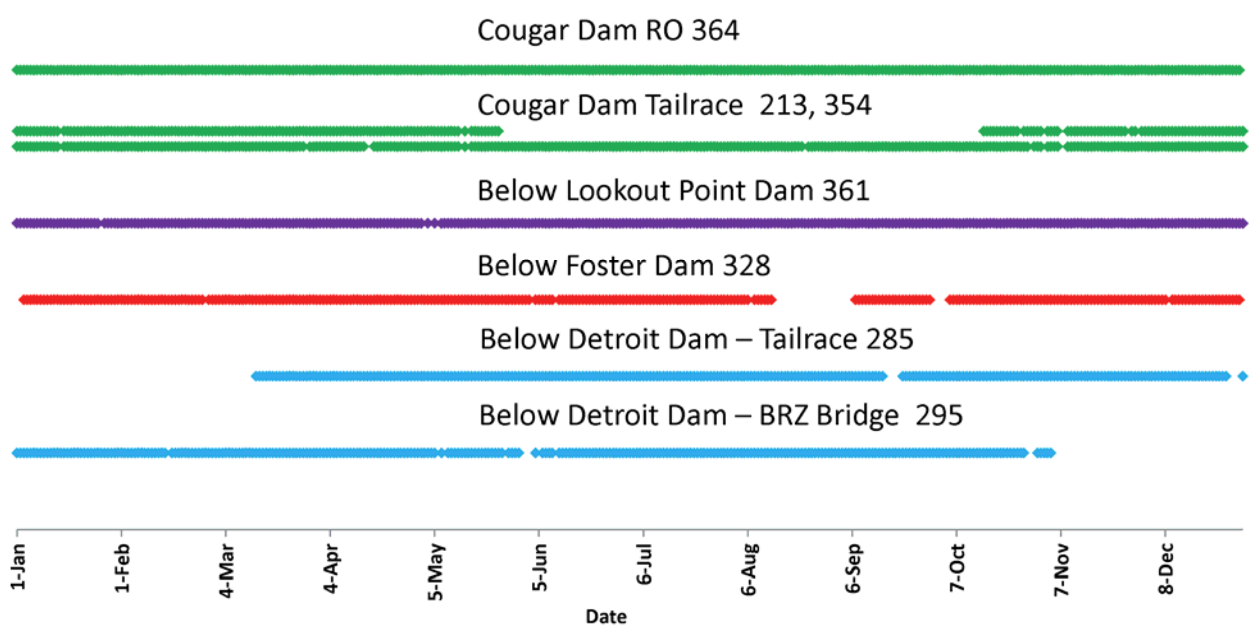

Figure 4. Screw trap operation summary for traps below dams in the upper Willamette Basin, 2013. Each colored dot represents one day of operation; numbers are the number of days the trap operated during the calendar year. Tailrace = turbine tailrace. BRZ = boat restricted zone. RO = regulating outlet.

Abundance Estimates of Outmigrating Chinook Salmon

We calculated capture efficiency weekly for each species and age class (based on fork length) by marking fish from each species and age-class category (we used PIT tags or a small clip from the caudal fin) and releasing the marked fish upstream ~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 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. If these criteria were not met for a particular sub-basin, the actual number of juvenile Chinook salmon captured was reported. Migrant abundance for periods when traps were stopped due to high flows or debris were estimated using the 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.

Methods used to estimate the number of live subyearling Chinook salmon exiting Cougar Dam in 2013 (2012 BY) were the same as those used to estimate the number of subyearlings migrating past our traps located upstream of reservoirs, with a few exceptions. We used only live fish captured below the dam for trap efficiency estimates, as live fish were the object of interest. We treated the two side-by-side traps in the tailrace (Figure 1) as a single unit for calculating trap efficiency. Trap efficiency and number of fish captured were likely lower when the farshore trap was not running; however, the methods for estimating the number of fish passing the trap account for this. We recaptured too few live yearlings (2012 BY) in 2014 to estimate trap efficiency. We therefore used the weighted trap efficiency from 2013 to estimate the total number of yearlings below the dam through April 23, 2014.

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. Few subyearlings were collected from mid-June - late December at any of the upstream trap sites, suggesting that the majority of juvenile Chinook salmon migrate into WVP reservoirs early in the spring.

The greatest catch in traps below project dams occurred primarily during late fall/early winter during reservoir drawdown and were comprised mainly of subyearlings. Two exceptions to this were below Lookout Point Dam where the greatest catch occurred May - June and was associated with surface spill events, similar to 2011 and 2012, and Foster Dam where most fish were caught during late spring.

North Santiam River- We operated the screw trap in the North Santiam River above Detroit Reservoir from March 8 - November 26, 2013. The run timing and size of subyearlings captured in the North Santiam trap were similar to subyearlings observed in the South Fork McKenzie River. The peak migration was from March - May (Figure 5) with a median migration date of May 14 (Appendix B; Table B2). Most subyearlings (63%) entered Detroit Reservoir during March - May as fry averaging 38 mm FL (Figure 6). The size range for subyearlings caught throughout the season was 32-122 mm FL.

The North Santiam trap fished for 234 d in 2013, and captured 311 Chinook salmon subyearlings, and seven yearlings (Figure 6). For comparison, in 2011 we captured 4,255 subyearlings in the North Santiam screw trap. The disparity in capture numbers between years is related to the number of females outplanted in the previous years (746 females in 2010; 98 in 2012; Appendix B; Table B1). There was a pulse of subyearlings that passed the trap in early October, soon after we were able to operate the trap following the high flow event. This late season migration was not observed in previous years.

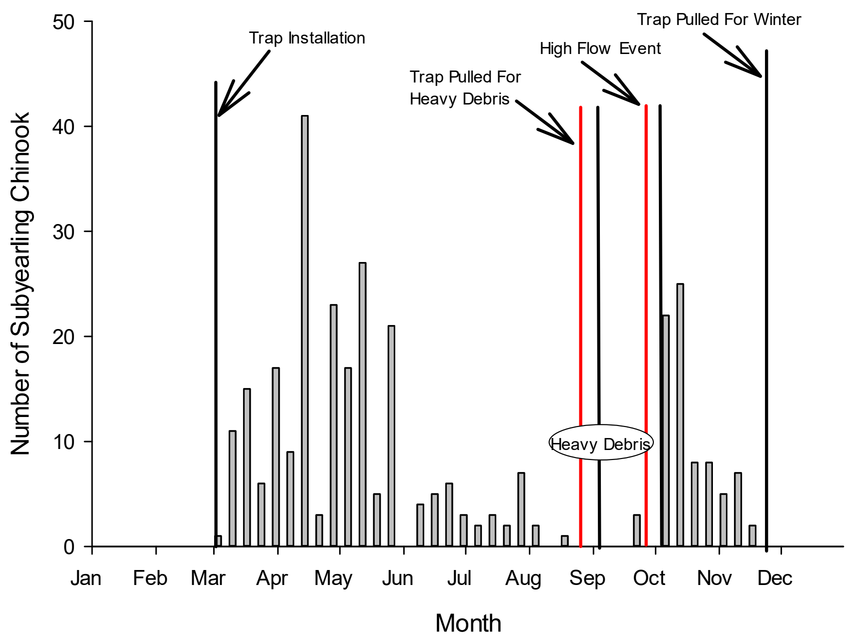

Figure 5. Weekly catch of subyearling spring Chinook salmon captured in the North Santiam trap above Detroit Reservoir, 2013. Red vertical lines indicate days when the cone was lifted and the trap was not fishing. Black lines indicate when the cone was lowered and the trap continued fishing unless otherwise noted in the text.

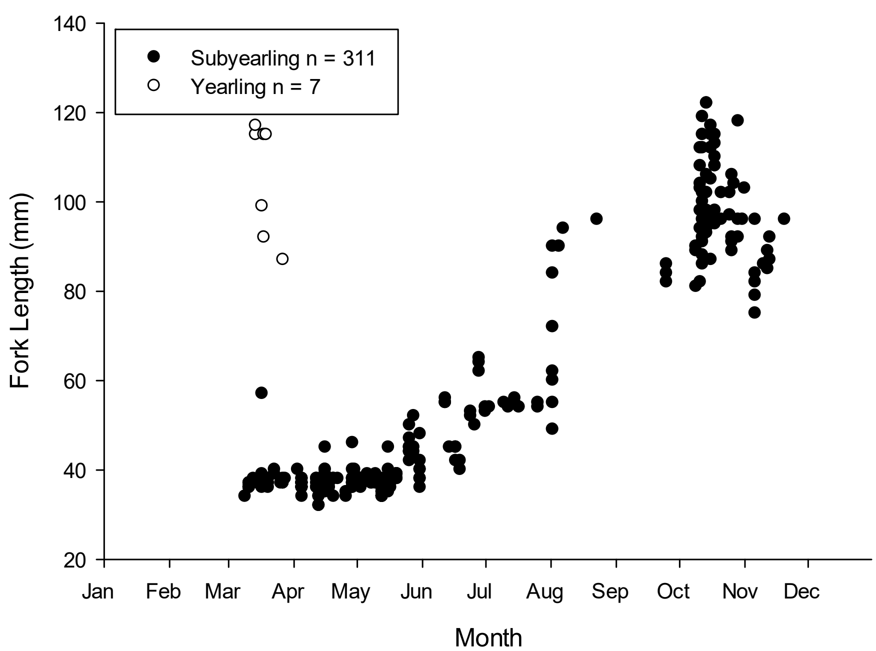

Figure 6. Fork lengths of juvenile Chinook salmon captured in the North Santiam trap above Detroit Reservoir, 2013.

Below Detroit Dam- We installed a new 2.4-m diameter screw trap directly behind the turbine outflow of Detroit Dam on March 13, 2013. The new tailrace trap operated 285 d in 2013. We also continued operation of our 1.5-m trap located at the BRZ bridge until November 5, 2013. Trapping conditions at this site remained highly variable as in previous years, making trap operation difficult. Due to safety concerns, we were unable to access the BRZ bridge trap at flows > 6,000 ft^3/s. The BRZ bridge trap operated 295 d, and the two traps overlapped in operation for 232 d (Figure 7).

Overall, capture numbers were low for the two traps located below Detroit Dam, and the trap directly behind the tailrace captured more fish than the downstream trap at the BRZ bridge (Figure 7) when both traps were operated simultaneously. The data is not directly comparable, as the tailrace trap primarily captures fish exiting the turbine tailrace, whereas the BRZ bridge trap could capture fish from the regulating outlet, spillway, or tailrace. To estimate individual trap efficiency, fish captured in the tailrace trap were marked with an upper caudal clip, and those captured at the BRZ trap were marked with a lower caudal clip. Of the 145 live and 20 dead Chinook (hatchery and naturally-produced) marked and released upstream for trap efficiency tests, only one dead naturally-produced Chinook (upper caudal clipped) was recaptured in the BRZ bridge trap. This suggests that trap efficiency was poor for both traps.

The BRZ bridge trap was removed just prior to the peak in subyearling outmigration past the dam in November. The combined trap catch below Detroit Dam in 2013 was 245 unmarked Chinook salmon, 225 hatchery Chinook salmon, and 1,073 kokanee *O. nerka*. Most of the Chinook salmon catch occurred at the tailrace trap in November (Figure 7). The overall mortality for each of these species recovered from the traps was 11%, 22%, and 88% respectively (29%, 20%, and 97% in 2012). The hatchery Chinook salmon originated from the release of ~99,000 PIT-tagged into Detroit Reservoir on June 27, 2013 (median FL 65 mm; Friesen et al. 2014 *in prep.*). Dam discharge, reservoir elevation and corresponding catch for all species summarized by month are presented in Appendix D, Table D1 and Figure D1.

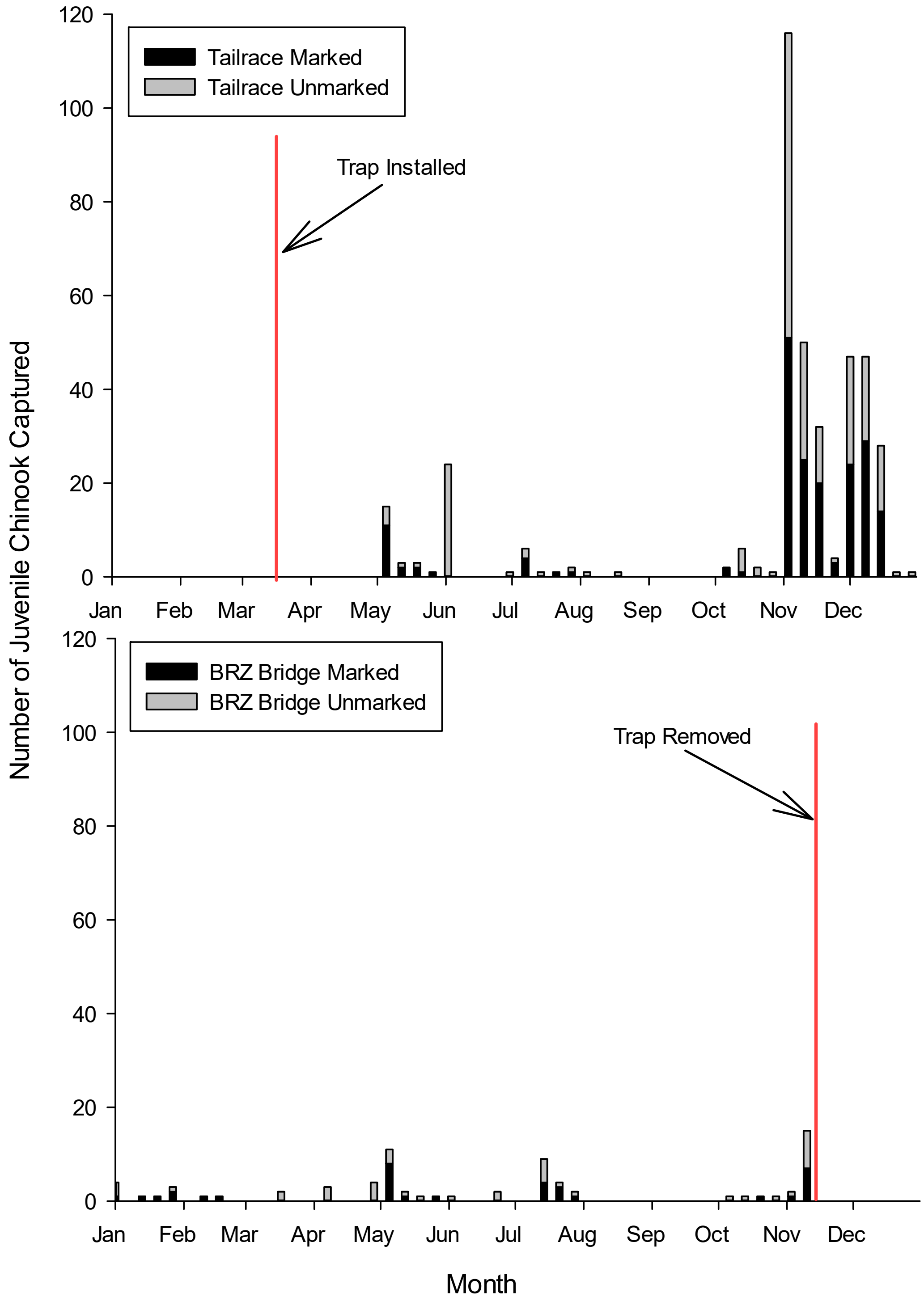

Figure 7. Weekly catch of marked and unmarked Chinook salmon (subyearling and yearlings) captured in the rotary screw traps below Detroit Dam, 2013. BRZ = boat-restricted zone.

Trap catches during periods of dam spill were too small to draw meaningful conclusions on fish passage. In 2013 spill operations started April 10. From April 10 – 16 (mean spill 0.76 kcfs; mean total discharge 0.94 kcfs) there was little discharge through the turbines. During this time we operated both traps downstream of the dam, and captured only three subyearling Chinook salmon. Similarly, spill occurred again from May 6 – 15 (mean spill 0.62 kcfs; mean total discharge 2.36 kcfs) while the turbines operated and we captured 31 yearling Chinook salmon. Overall, there was an increase in catch throughout May and July while spill and power generation were occurring as part of summer temperature control operations, similar to 2012. However, we did not observe increased numbers of juvenile Chinook salmon passing through Detroit Dam in August - September in 2013 like we did in 2011 and 2012 associated with increased discharge through the turbines. We included dam operation and discharge information (Appendix D; Figure D1) to provide context for the fish trapping data.

South Santiam River Spring Chinook Salmon- We operated the South Santiam trap upstream of Foster Reservoir from January 7 through November 30, 2013. The trap fished for 314 d. Catch of juvenile Chinook salmon increased from previous years and they were captured throughout the year (Figure 8). We captured 729 subyearlings and two yearlings in 2013 (Figure 9). Peak fry movement was in February and March (Figure 8), with a median migration date of February 28. The South Santiam Chinook salmon emerged earlier than other sub-basins, grew quickly, and fish captured in the screw trap upstream of Foster Reservoir were larger and more variable in size than their stream-rearing counterparts in other sub-basins (Figure 19). Emergence timing and growth were most similar to juveniles from the Middle Fork Willamette River.

The number of subyearlings captured in 2013 (2012 BY) was nearly five times the number captured the previous year even though there were 153 fewer adult females released into the South Santiam River in 2012. In 2012 we captured 147 subyearlings (2011 BY) and one yearling, with 97% of all juvenile Chinook salmon captured prior to May 1. Differences in maximum winter flows among years may partly explain difference in trap catches. The highest flow experienced by 2012 brood year Chinook in the South Santiam River was 8,640 ft^3/s on November 20, 2012, while eggs were still in the gravel (<10,000 ft^3/s) and the highest flow while fry were emerging was 2,460 ft^3/s (January 29, 2013). The two previous brood years (BY 2010 and 2011) were subjected to flow >10,000 ft^3/s in mid-January (Figure 10). A high flow event on January 16, 2011 (2010 BY) peaked at 26,900 cfs, a flow level in the South Santiam River not reached since 1999. It should be noted that in previous reports we stated the mean daily flow for this date was 11,800 cfs based on provisional USGS data at gauging station 14158000 near Cascadia. The mean daily flow for this date has since been estimated at 18,000 cfs.

In 2013, with the absence of high flow events early in the year, we captured Chinook through November, with a small pulse of fish that we have not previously observed moving downstream in July (Figure 10). The small catches observed in 2011 and 2012 coupled with the increased number of juvenile Chinook salmon in 2013 further suggest that high flow in mid-January may not be conducive to egg incubation and in-stream rearing for juvenile Chinook salmon, as previously suggested (Romer et al. 2013). The South Santiam River above Foster has a deeply incised channel, and a majority of the accessible spawning substrate is perched on bedrock (Romer et al. 2012). High flows that occur early in the year may push fry downstream into

Foster Reservoir or displace redds, causing direct mortality to eggs and alevins residing in the interstitial spaces of the substrate.

Figure 10 illustrates the flow conditions for spring Chinook salmon eggs and fry in the South Santiam River at or near the time of emergence for brood years 2010-2012. Fry emergence timing was estimated based on stream temperatures and the calculation of accumulated thermal units (ATU; Connor et al. 2003; Geist et al. 2006; Groves et al 2008). We used September 15 as the standardized start date for the ATU calculations because this date typically corresponds to a period of increased redd construction preceding the peak number of redds observed, which usually occurs during late September – early October (Sharpe et al. 2014). Adults from the 2010 brood year should be returning in 2014, as a majority of fish from the upper Willamette Basin return as age-4 adults (Johnson and Friesen 2013) and should lend some insight to whether these high flows near the time of emergence contribute to poor cohort survival, or newly emergent fry are pushed downstream and are able to survive and successfully rear elsewhere.

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

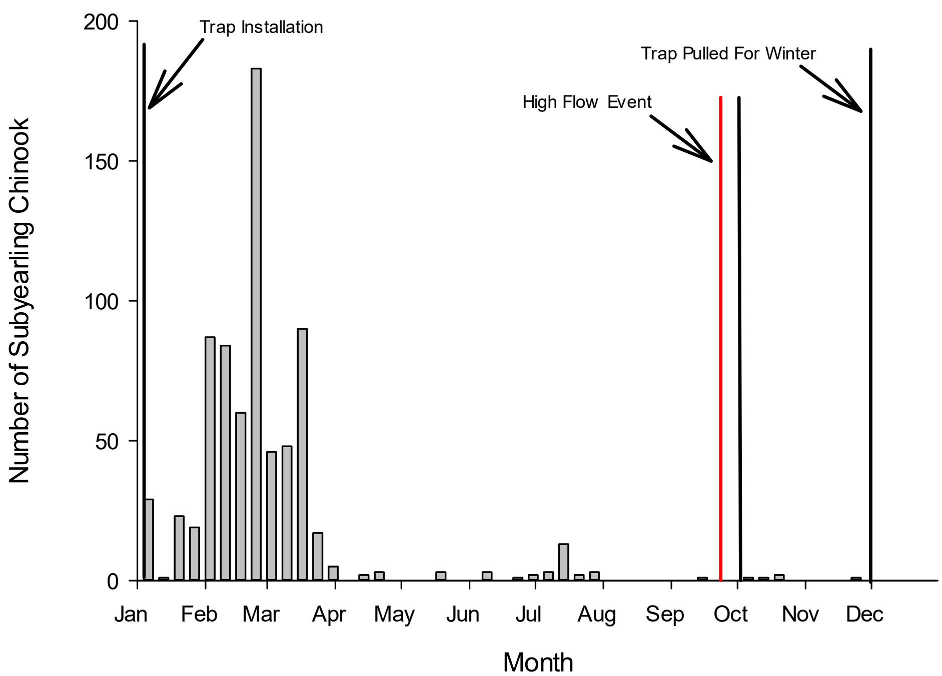

Figure 8. Weekly catch of subyearling spring Chinook salmon captured in the South Santiam trap above Foster Reservoir, 2013.

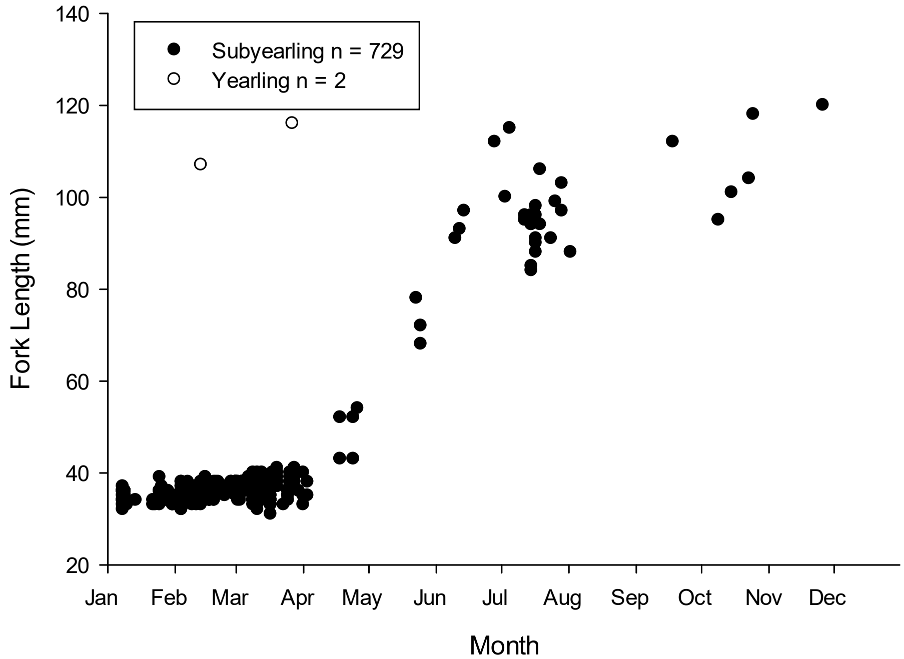

Figure 9. Fork length of subyearling and yearling Chinook salmon collected in the South Santiam trap above Foster Reservoir, 2013.

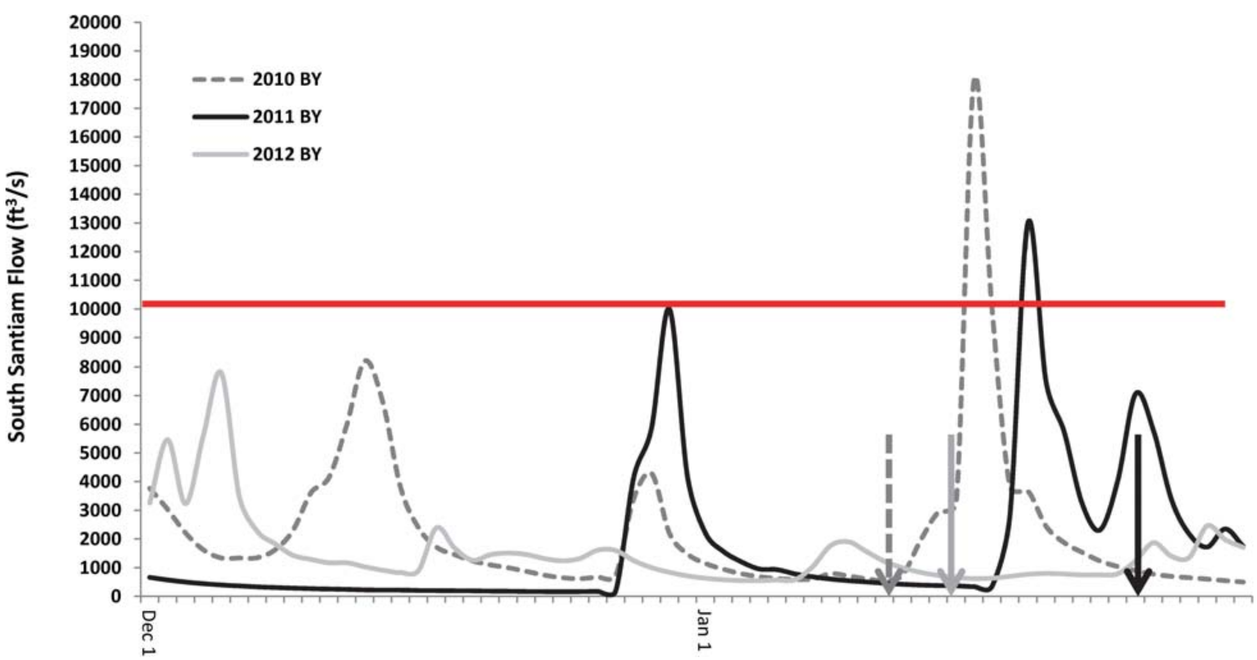

Figure 10. Flow and accumulated thermal units (ATU=1,000) calculated using mean daily flow and mean daily temperature (°C) values from USGS gauging station on the South Santiam River near Cascadia (14158000) upstream of Foster Reservoir. Arrows represent the estimated date of emergence and corresponding flow data for each brood year (2010-2012) using September 15 as the standardized start date of egg incubation. The red horizontal line denotes 10,000 ft^3/s.

South Santiam River Winter Steelhead- Juvenile steelhead exist in sympatry with resident rainbow trout in the South Santiam River and cannot be distinguished from one another in the field; we refer to both life-history types as *O. mykiss.* We captured 865 juvenile *O. mykiss* in the South Santiam screw trap in 2013 and based on length-frequency distributions, there were at least three distinct year classes present (Figure 11). In previous years we captured very few (1 - 7) age-2 *O. mykiss* in our trap but in 2013 we captured 35, with 91% passing the trap in April-May consistent with expected smolt outmigration timing. We suspected *O. mykiss* > 250 mm FL were resident rainbow trout but were included here as age-2 because we are unable to definitively determine age without scale analysis. We plan to collect scales from *O. mykiss* in 2014 to determine the age of larger fish.

Subyearling *O. mykiss* were presumably progeny of adult steelhead outplanted above Foster reservoir. The first subyearling from the 2013 BY was captured on June 14 (30 mm FL), one week earlier than in 2012. Catch peaked in July and continued through November (Figure 12). The subyearling cohort reached a maximum FL of ~100 mm and comprised 77% of the total *O. mykiss* catch for the year. Other year classes (presumably ages 1 and 2) were also present, with a size range of ~100-210 mm FL (Figure 11).

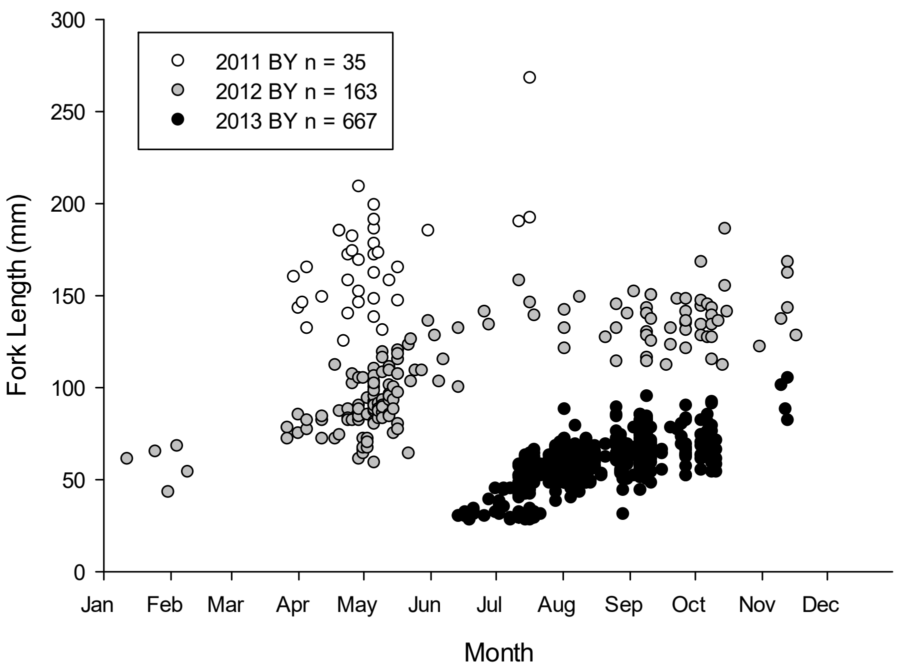

Figure 11. Fork lengths of *O. mykiss* caught in the South Santiam trap above Foster Reservoir, 2013.

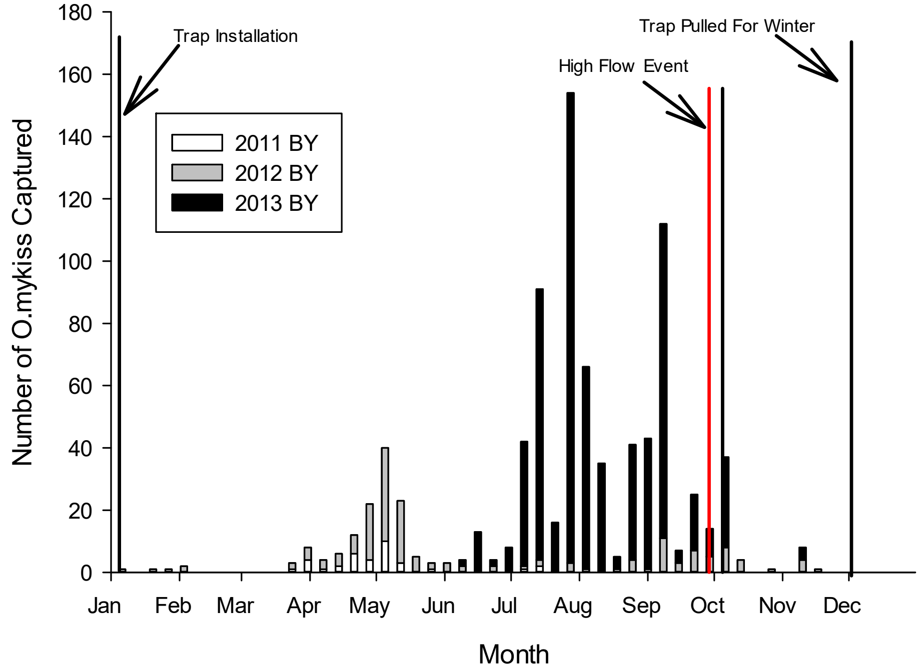

Figure 12. Weekly catch of juvenile *O. mykiss* captured in the South Santiam trap above Foster Reservoir, 2013. BY = brood year.

We sampled Foster Reservoir for the first time in 2013 and initiated PIT-tagging of *O. mykiss* juveniles > 65 mm FL on March 8. Throughout the year we tagged 430 *O. mykiss* in the reservoir. In April-June natural-origin *O. mykiss* were the most common species captured in the forebay of Foster Reservoir near the dam, but we only captured four *O. mykiss* in our screw trap in the tailrace below the dam during that period (three were prior to weir installation). Based on PIT-tag detections downstream at Willamette Falls, we suspect many of the *O. mykis*s in the forebay exited the reservoir in the spring and either avoided our screw trap or used a spillway/weir passage route. Among *O. mykiss* tagged in Foster Reservoir, 110 were smolt-sized (≥ 120 mm) and were tagged from March-May (n = 96 in April); 12 were detected at Willamette Falls (Figure 13). Assuming an estimated detection efficiency at the bypass detection array at Willamette Falls of ~25% (Luke Whitman, ODFW, *pers comm*.) for the flow levels during this period, the 12 detections expanded to an estimated 48 fish ≥ 120 mm (44%) leaving the reservoir and surviving to Willamette Falls. All fish (except one) detected at the falls were tagged in the lower zone of the reservoir near the dam, and all were > 120 mm FL at the time of tagging. Average travel time from time of tagging in Foster Reservoir to Willamette Falls, a distance of 211 rkm, was 23 d (range 6-50 d). Three additional tagged fish that were not detected at the bypass antenna at Willamette Falls were detected farther downstream in the Columbia estuary by the surface pair-trawl (Ledgerwood et al. 2004) or on East Sand Island (Evans et al. 2012). The latest detection at Willamette Falls for any of the *O. mykiss* tagged in Foster Reservoir was May 30, 2013.

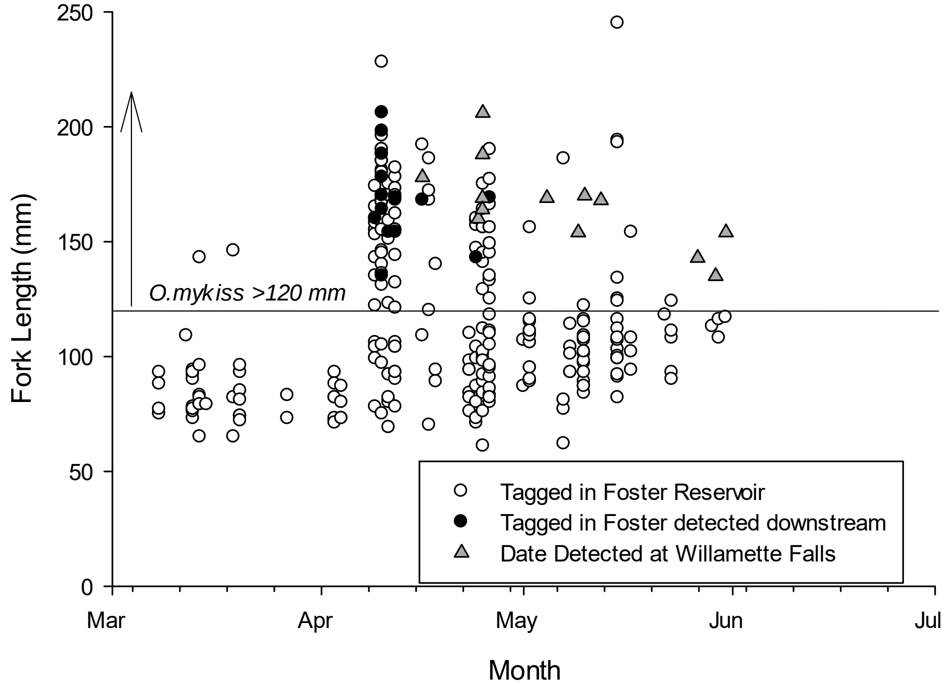

Figure 13. Date and size at tagging for all *O. mykiss* PIT-tagged in Foster Reservoir (all dots). Black dots represent the date of tagging for all fish that were detected downstream (Willamette Falls, Columbia River Estuary, or East Sand Island) and the grey triangles represent the detection date of those same fish subsequently detected at Willamette Falls. Arrow indicates *O. mykiss* >120 mm.

Below Foster Dam - The trap below Foster Dam operated from January 2 – December 30, 2013. The trap ran 90% of the days that were available for fishing (328/364). This trap was removed from service August 14-September 6 (it was inaccessible due to the construction of the adult collection facility), and again September 30 – October 4 for a safety inspection. 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 163 unmarked subyearling Chinook salmon throughout the year, beginning February 4. Most of the subyearlings (71%) were captured from February - March (Figure 14) with a mean size of 38 mm FL (range: 31-49 mm FL); timing and size were similar to fish entering the reservoir. The migration timing and size of subyearling Chinook salmon collected below the dam suggests that some subyearling Chinook salmon moved through Foster Reservoir into downstream rearing areas when the reservoir was at lower pool elevation (Appendix D; Figure D2). Our screw trap is positioned just downstream of the turbine outflow and is unable to sample fish exiting via the spillway. However, given the shallow turbine penstocks, our screw trap catch in the tailrace likely reflects overall trends in migration timing and relative abundance of subyearling salmonids, regardless of passage route.

We also captured 38 *O. mykiss* below Foster Dam, compared to 141 in 2012. The first subyearling *O.mykiss* was captured below the dam on October 9. Peak outmigration for young of the year *O. mykiss* below Foster dam was in October (Figure 14), and appeared to be delayed in comparison to the capture of new emergents upstream of the reservoir which peaked in late July (Figure 12). In contrast to Chinook salmon, most subyearling *O. mykiss* enter the reservoir at full pool elevation with a greater distance to travel and less flow through the reservoir for guidance due to decreased flow from the South Santiam River and decreased discharge at Foster Dam. Most subyearlings and age-1 *O. mykiss* were captured October – December, while three of the five age-2 *O. mykiss* were captured in April, consistent with the expected peak of smolt migration timing (Figure 15).

Foster Weir - The Foster Dam fish weir, deployed to facilitate juvenile *O. mykiss* passage through the reservoir, was operated in spillway 4 from April 15 to May 15 in previous years. Weir operation dates were originally based on the outmigration timing of winter steelhead smolts, progeny from adult hatchery winter steelhead that were outplanted upstream of Green Peter Reservoir (Wagner and Ingram 1973). Similarly, in the nearby Clackamas River (and several associated sub-basins), juvenile winter steelhead downstream movement peaks in April and May (Strobel 2006; Wyatt 2009). However, our previous data suggested that the duration of weir operation may not coincide with downstream migration timing for all age classes of juvenile *O.mykiss* from the South Santiam River (Romer et al. 2013). Migration data collected upstream and downstream of Foster Reservoir suggest that weir operations or surface spill during the fall and winter months may be more effective for moving subyearling *O. mykiss* through the reservoir. Buchanan et al. (1984) suggested that passage through subsurface routes combined with spill at high discharge (> 3,400 ft^3/s) and low reservoir level increased smolt passage and contributed to higher smolt-to-adult survival rates.

In 2013 the weir was installed on April 11 and continued to operate periodically throughout the year (Figure 16). The weir was not operating May 1 – 7 during spring refill or September 27

– October 17 for winter drawdown. Our PIT-tagging information discussed previously (Figure 13) suggests that the screw trap in the turbine tailrace of Foster Dam captures very few smolts exiting Foster Reservoir. Steelhead smolts (≥ 120 mm) may be passing over the spillway where we are not able to capture them in our screw trap, or smolts exiting turbines are large enough to avoid the trap. Therefore, screw trap catch may not accurately reflect the number of fish passing the dam through the weir. In May 2014, a PIT antenna will be installed on the weir and PIT-tagged Chinook salmon and *O. mykiss* will be detected as they pass through the weir gate, providing additional information about outmigration timing, route selection, relative abundance, and rearing behavior, and will help verify acoustic fish passage information collected by Pacific Northwest National Laboratory (PNNL).

Typical life history patterns observed for naturally-produced winter steelhead are dominated by age-2 smolts in the Columbia and Snake rivers as well as coastal Oregon streams where there are sufficient data available (Busby et al. 1996). Our trapping and tagging data suggest that a majority of the winter steelhead in the South Santiam River move downstream past our trap as subyearlings and continue to rear farther downstream. These fish then subsequently migrate to the ocean as primarily age-2 smolts. The proportion of each year-class that rear in Foster Reservoir is unknown. Data collected from our trapping and tagging efforts above Foster Reservoir, in the reservoir, and below Foster Dam in conjunction with the new PIT-tag antenna on the Foster Dam weir (installed May, 2014) and the antenna at Willamette Falls should provide greater insight on the migration behavior of winter steelhead from this sub-basin. It will also allow collection of information regarding movement and growth of resident *O. mykiss* if we recapture tagged fish in our screw trap upstream of the reservoir as they undergo in-stream migration associated with resident spawning behavior.

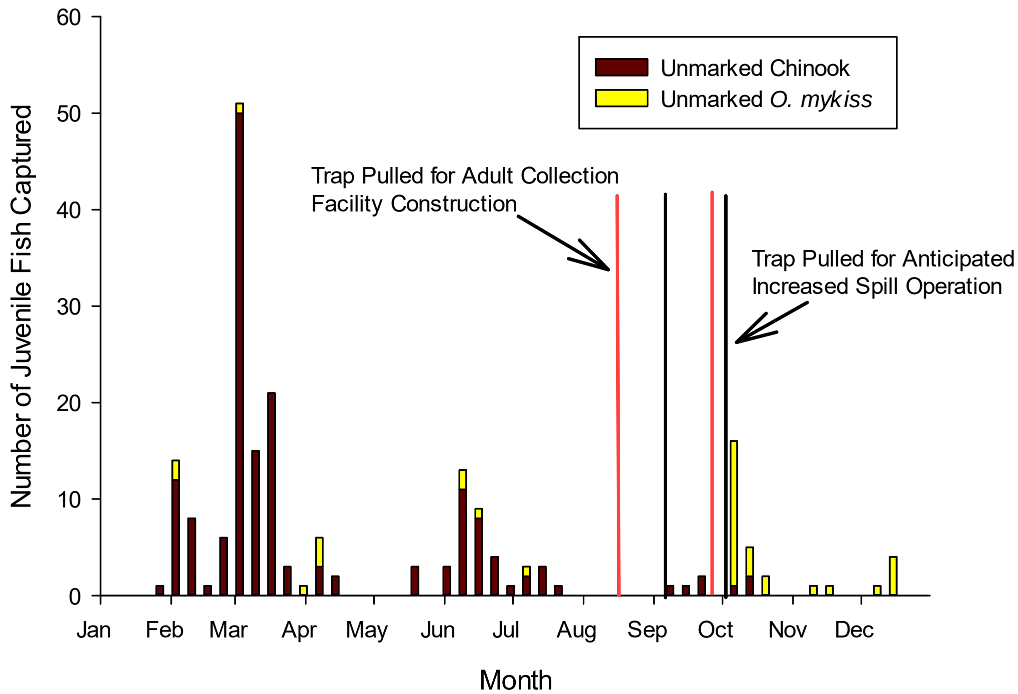

Figure 14. Weekly catch of unmarked Chinook salmon and *O. mykiss* captured below Foster Dam, 2013.

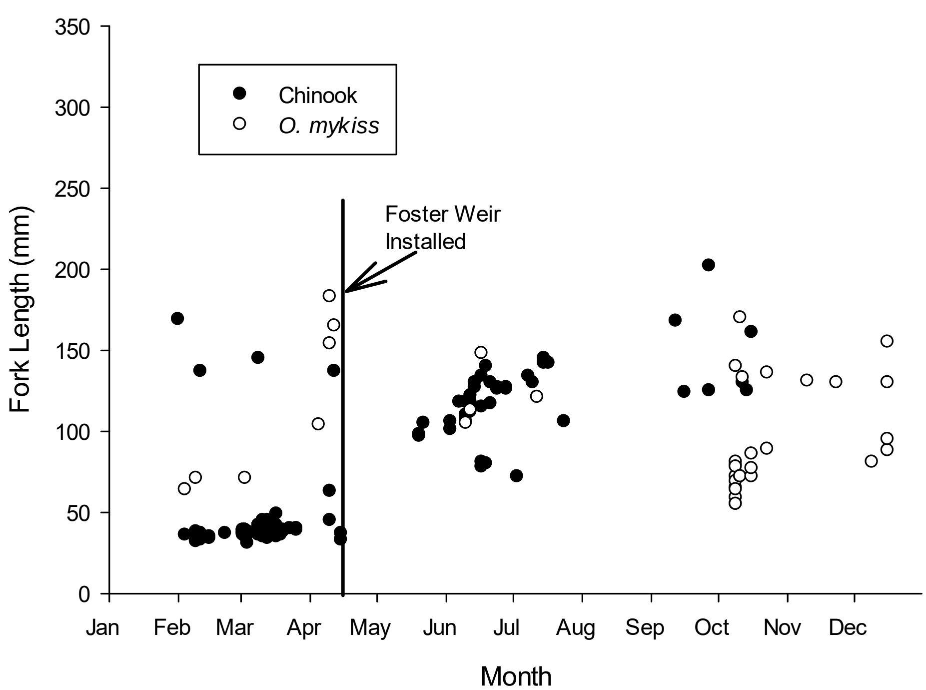

Figure 15. Fork lengths of unmarked juvenile spring Chinook salmon and *O. mykiss* captured in the rotary screw trap below Foster Dam, 2013. The black vertical line represents the installation of the Foster Dam fish weir.

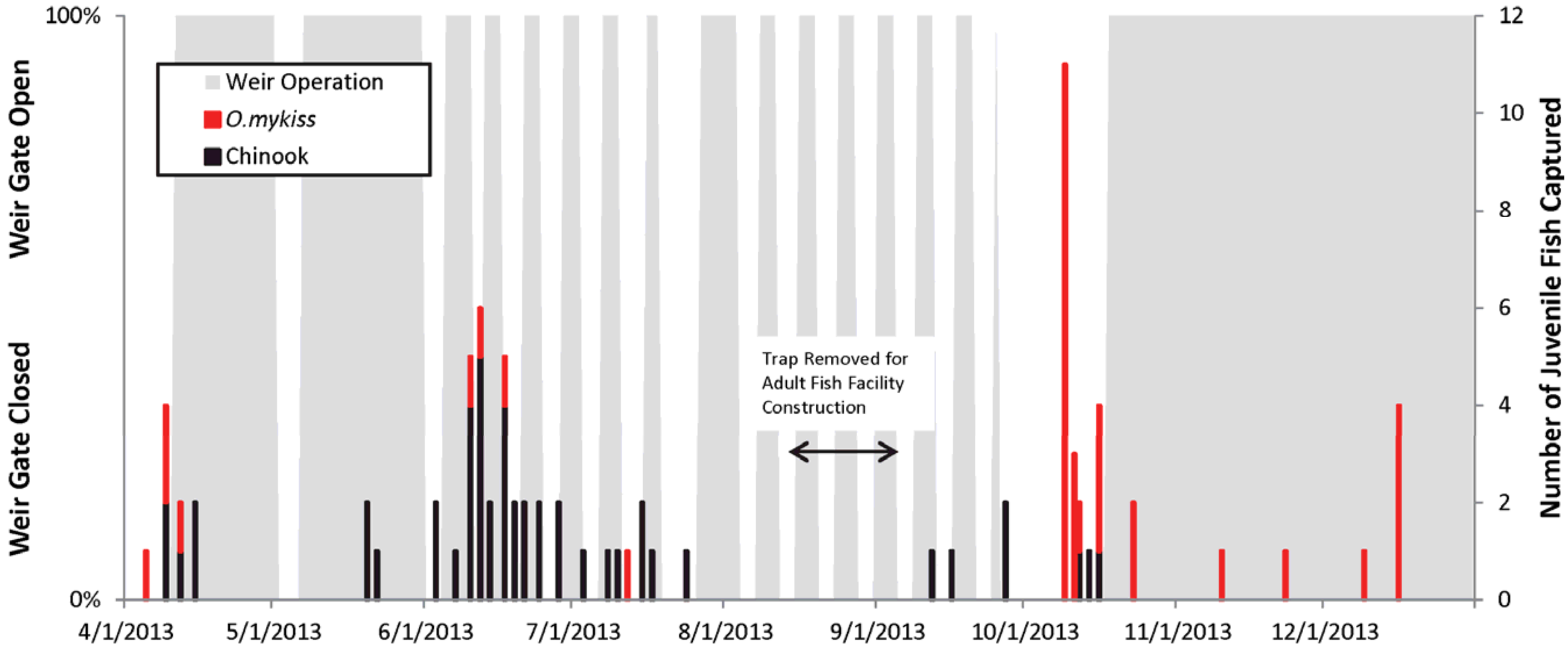

Figure 16. Daily number of unmarked juvenile salmonids captured in the screw trap below Foster Dam from April – December, 2013. Shaded areas denote when the weir gate was open. White areas denote periods when the weir gate was closed or otherwise not operating.

Middle Fork Willamette River- We operated the Middle Fork Willamette (MFW) River trap upstream of Lookout Point Reservoir from February 12 through November 14, 2013. The trap fished for 259 d and captured 1,912 Chinook salmon subyearlings and 67 yearlings. The peak of the fry migration was February-June (Figure 17), and the median migration date was April 4 (Appendix B; Table B2). The size range for subyearlings was 29-119 mm FL (Figure 18). In 2011 (2010 BY), we captured a large number of subyearlings near the beginning of January (n = 62, mean 34 mm FL, SE 0.16 mm), presumably due to increased flows that were pushing newly emerged fry downstream. In 2012 and 2013 we did not begin fishing the trap until mid-February, and captured juvenile Chinook salmon immediately subsequent to trap deployment both years. There were no high flow events in January 2012 or 2013 but we likely missed some of the early emergent juveniles migrating past the trap site. This may have slightly influenced the median migration dates from the 2012 and 2013 trapping seasons. The mean size of fry captured in February 2013 in the MFW was 35 mm FL (n = 120, SE 0.13), compared to36 mm in 2012 (n = 62, SE 0.24).

Fish captured in the MFW trap upstream of Lookout Point Reservoir exhibited greater variation in fork length than any of the other trapping sites other than the South Santiam (Figure 19). As documented in previous reports (Romer et al. 2012, 2013), several factors may contribute to the prolonged subyearling migration timing and large variation in size of migrants. First, the trap was located 58 km from the furthest known upstream spawning area in the North Fork Middle Fork Willamette River, where most of the spawning in this sub-basin takes place. This is nearly twice the distance of any of the other traps in relation to upstream spawning areas. Second, some subyearlings may reside longer in the relatively high-quality rearing habitat present in the North Fork Middle Fork Willamette River before migrating downstream. Finally, trap catch was likely confounded by juvenile Chinook salmon (marked and unmarked) emigrating out of Hills Creek Reservoir. These variables, along with the higher temperatures, may explain why fish captured in the MFW trap were typically larger than their counterparts rearing in the other sub-basins.

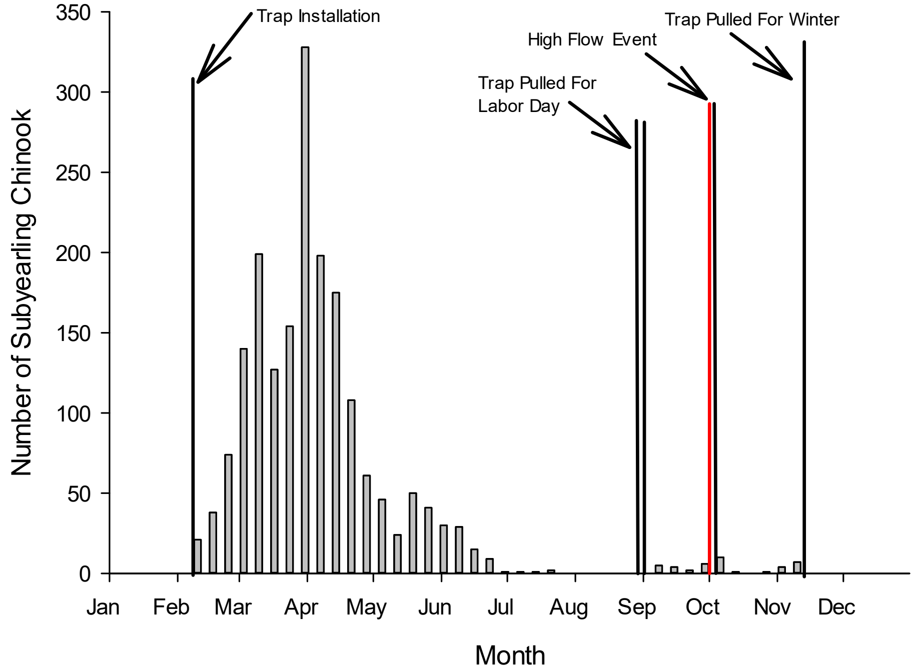

Figure 17. Weekly catch of subyearling spring Chinook salmon captured in the Middle Fork Willamette trap upstream of Lookout Point Reservoir, 2013.

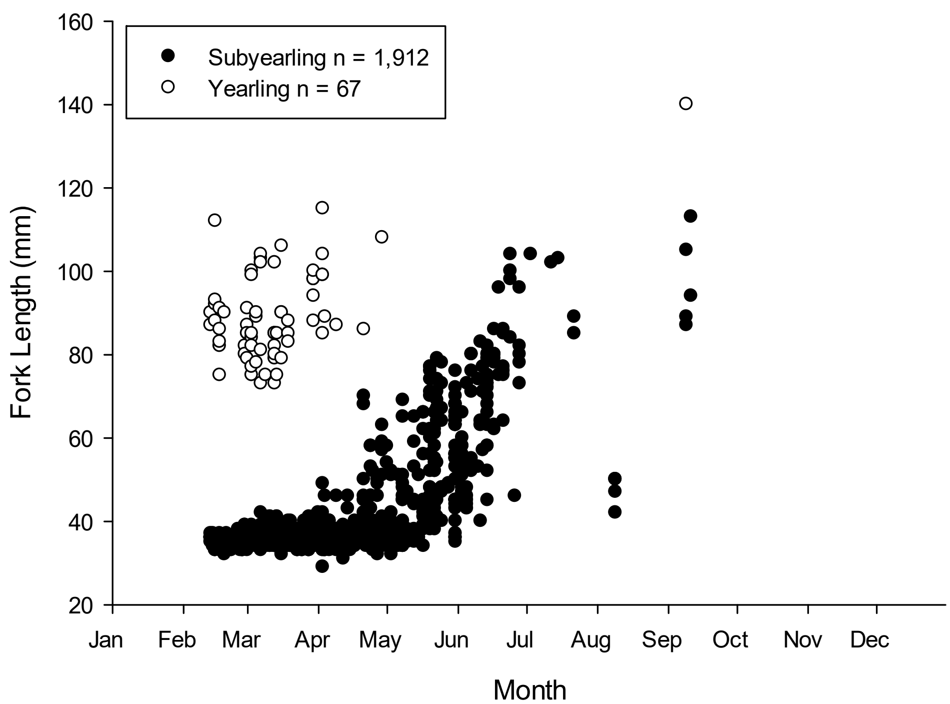

Figure 18. Fork length of subyearling and yearling Chinook salmon collected in the Middle Fork Willamette trap, 2013.

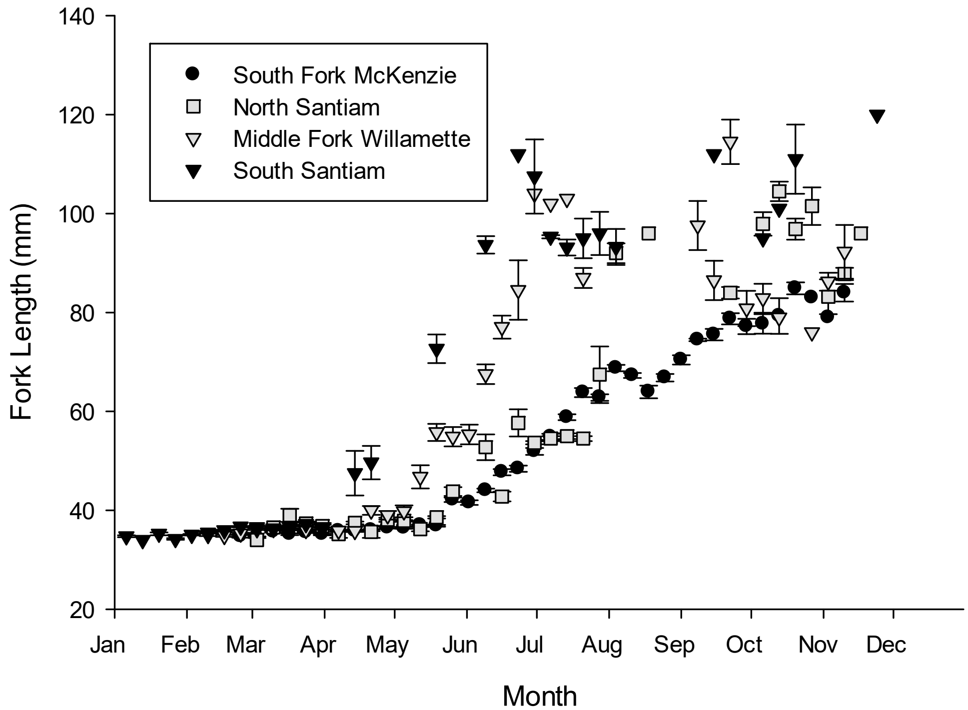

Figure 19. Comparison of growth for subyearling spring Chinook salmon at each upstream screw trap location, 2013. Data were summarized by week and error bars represent the standard error.

Below Lookout Point Dam- Personnel from USACE operated a 2.4-m screw trap below Lookout Point Dam from January 1 to December 31, 2013. The trap captured 37 hatchery and 31 unmarked juvenile Chinook salmon (subyearling and yearling). Catch included six fry; the first three were collected February 1, 2013, similar to the first capture of fry below the dam in 2011 (2010 BY). In 2012, the first fry was not collected until April 26. Capture numbers for Chinook salmon were low compared to other traps located downstream of project reservoirs. Dam discharge, reservoir elevation and corresponding catch for all species summarized by month are provided in Appendix D; Table D3 and Figure D3.

On May 31, 33,000 PIT-tagged hatchery Chinook salmon were released near the head of Lookout Point Reservoir and 33,000 near the forebay by ODFW as part of an ongoing paired release study (median 68 mm FL; Friesen et al. 2014 *in prep*). Dam discharge (Figure 22) was controlled from April through June to mimic the discharge from 2011 and 2012 to maintain consistency and allow comparison of paired release data among years. Spillway discharge resulted in an increased number of Chinook salmon captured below the dam in May and June (Appendix D; Table D3). Until recently, increased spill during summer months was atypical relative to historical flow management regimes (Romer et al. 2012), and previously, juvenile Chinook salmon in the Middle Fork Willamette River exited Lookout Point Reservoir between November and February (Keefer et al. 2013). The November - February outmigration period is consistent with data we have collected from most traps below dams in other upper Willamette sub-basins.

South Fork McKenzie River- We operated the South Fork McKenzie trap upstream of Cougar Reservoir from February 28 to November 14, 2013 and the trap fished for 252 d. The peak fry capture occurred in the South Fork McKenzie from March - May (Figure 20), with a median migration date of April 26 (Appendix B; Table B2). The distinct migration of subyearlings in early spring at this trap site was consistent with previous work (Bureau of Commercial Fisheries 1960; Monzyk et al. 2011; Zymonas et al. 2012; Romer et al. 2012, 2013;). Overall, we collected 20,082 Chinook salmon subyearlings and nine yearlings. Growth of the subyearling cohort upstream of the reservoir was not evident until the end of June (Figure 21).

The size of subyearling Chinook salmon ranged from 31-98 mm FL, and the mean fork length from March through May was 36 mm (n = 1,804, SE 0.066), approximately the size at which most of them would be entering the reservoir. Interestingly, five albino fry (36-37 mm FL) were captured April 2-24. Very few yearlings were captured upstream of the reservoir. No yearlings were captured after July, in contrast to 2012, when several precocious males were captured in September and October. These fish were milting and four of the five were infected with copepods, suggesting that they had spent time rearing in Cougar Reservoir.

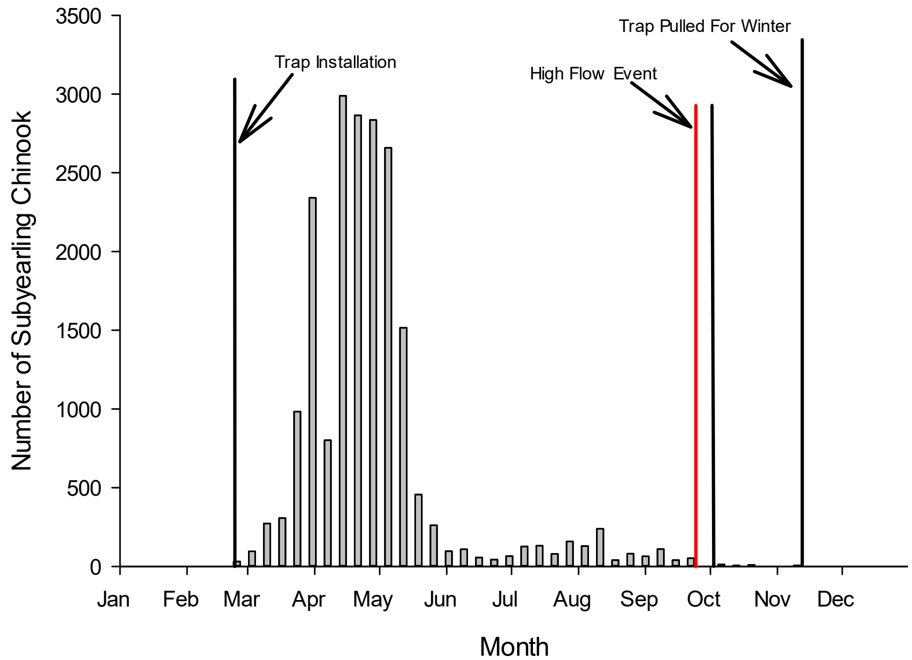

Figure 20. Weekly catch of subyearling spring Chinook salmon captured in the South Fork McKenzie trap above Cougar Reservoir, 2013.

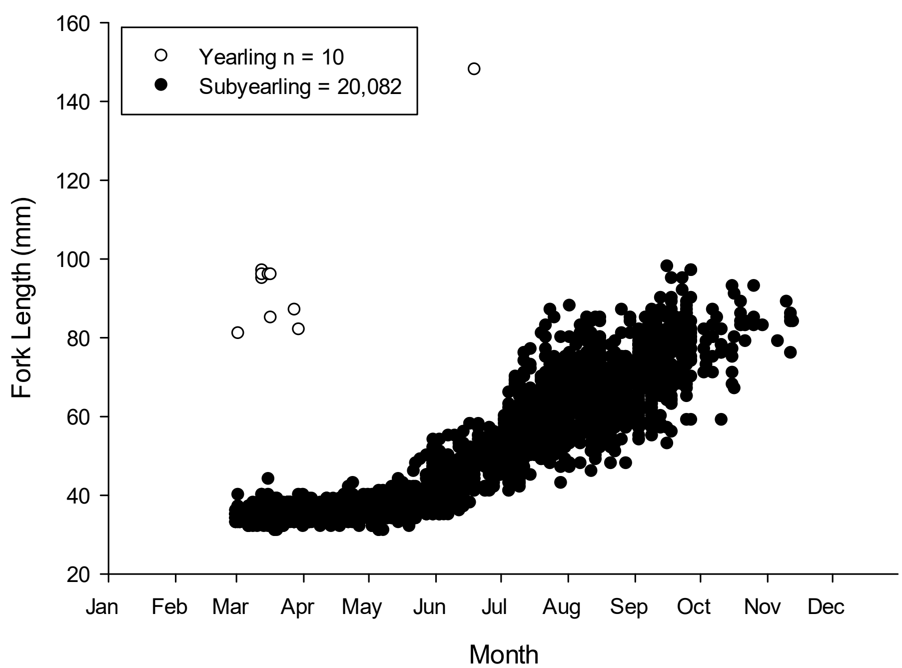

Figure 21. Fork length of subyearling and yearling Chinook salmon collected in the South Fork McKenzie trap above Cougar Reservoir, 2013.

Below Cougar Dam – We operated three rotary screw traps below Cougar Dam for a majority of the 2013 field season. From May 25 – Oct 14 the trap farthest from shore in the Cougar tailrace did not operate because the trapping site was too shallow for the cone to spin. Total trap catch from all traps below the dam included 4,323 subyearling and 243 yearling unmarked Chinook salmon (Figure 23, Appendix D; Table D4). We captured 311 subyearling fry (< 60 mm FL) in the traps below Cougar Dam (four in the RO trap; 307 in tailrace traps) from April 5 – June 26, when most discharge was through the turbines (Figure 28). The first subyearling was collected in the screw trap upstream of Cougar Reservoir on March 1, 2013. This suggests that though migration is delayed, some fry traversed the reservoir and survived passage through both routes. Most subyearlings were collected in November from the RO trap, coinciding with increased discharge through the RO and decreasing reservoir elevations (Figure 22 and 23). Dam discharge, reservoir elevation and corresponding catch for all species summarized by month are provided in Appendix D; Table D4 and Figure D4.

In previous years we captured several hundred yearling Chinook salmon passing the dam in January (range 288-563 from 2010-12). Chinook salmon passing Cougar dam in January 2013 are considered yearlings from the 2011 BY and only six yearlings were captured in the month following the deep drawdown in December 2012. The relative scarcity of yearlings was not the result of increased passage during the deep drawdown, as we did not observe increased catch during that operation compared to previous years (Romer et al. 2013). However, there was little discharge from the dam from January-March as the reservoir refilled following the deep drawdown (Figure 28).

Interestingly, 31% of all yearlings collected below Cougar Dam in 2013 were captured in November (Figure 23). In previous years we did not observe this many yearlings rearing an additional summer in the reservoir. We are unsure if this delayed outmigration of yearlings in November 2013 was related to the deep drawdown and the subsequently low discharge conditions earlier in the year, as the reservoir refilled. It is possible that less discharge may have resulted in less yearlings outmigrating early in the year and partially explains the observation yearlings throughout the remainder of the year.

Passage Summary (BY 2009-2012) - Peak outmigration from the dam for each brood year of Chinook salmon typically occurs between November and February (Figure 22; Taylor 2000; Romer et al. 2012; Zymonas et al. 2012). Although fish are from the same brood year, the age class (subyearling or yearling) is determined by the calendar year. For example, juveniles from the 2010 brood year that outmigrated in November and December 2011 were considered subyearlings and comprised a majority of the fall outmigrants. Juveniles from the same cohort (2010 BY) comprised the majority of the spring yearling migrants in 2012. Although spring outmigrants are primarily yearlings, some older fish (>200 mm FL) and subyearling fry (<60 mm FL) are also captured during this period (Figure 23).

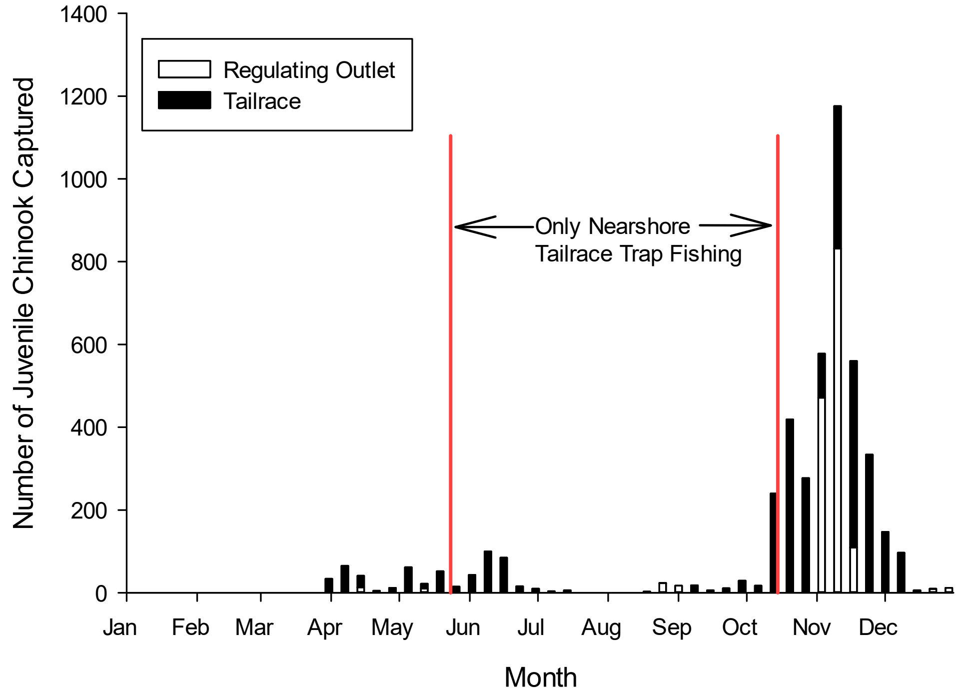

Figure 22. Weekly catch of unmarked juvenile spring Chinook (subyearling and yearlings) captured below Cougar Dam in rotary screw traps, 2013.

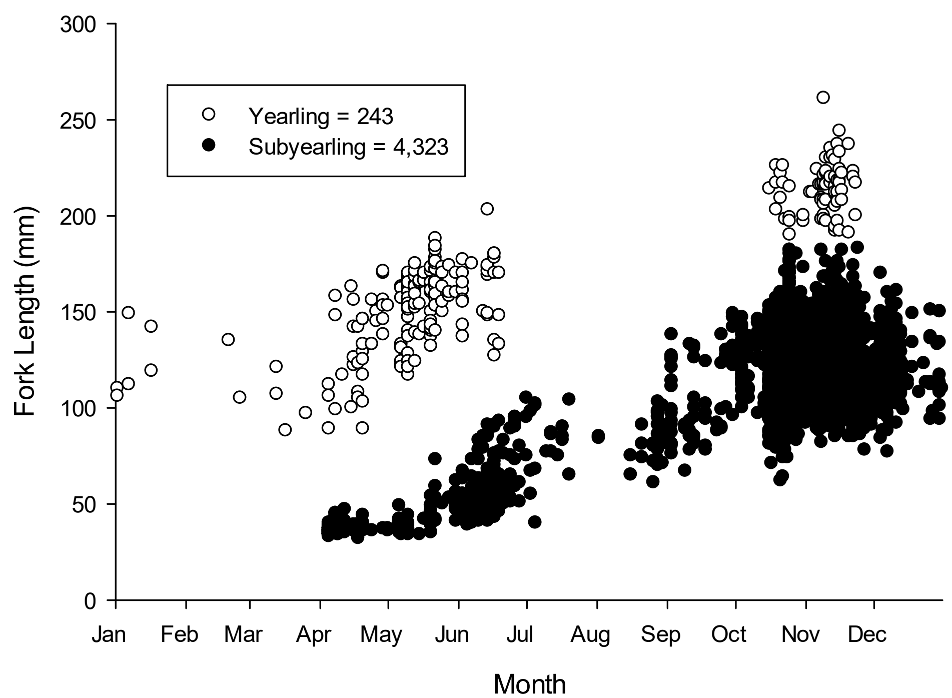

Figure 23. **Relationship between fork length and capture date for natural-origin juvenile Chinook salmon below Cougar Dam, 2013**.

To illustrate the effect of reservoir and dam passage on timing and growth of juvenile Chinook salmon in the South Fork McKenzie River, we graphed the average fork length and number of spring Chinook salmon captured in our screw traps (summarized by month) for several brood years of fish (2009-2012) captured above and below the Cougar Project (Figure 24). Essentially, we followed each brood year of juveniles (ex., 2010 BY) as they moved into and through the project over a 22-month period, starting when they emerge from the gravel (February 2011) and enter Cougar Reservoir (peak reservoir entry April – June 2011) to when nearly all of the fish from that brood year have passed the dam (December 2012; peak dam passage October 2011 to January 2012). This also helps to visualize the relative size of the cohorts, and the variations in timing and growth among years. The Cougar Project delays downstream migration an average of five months (May-September) from the beginning of the ascending limb of peak migration into the reservoir in April to the beginning of the peak migration out of the dam in October.

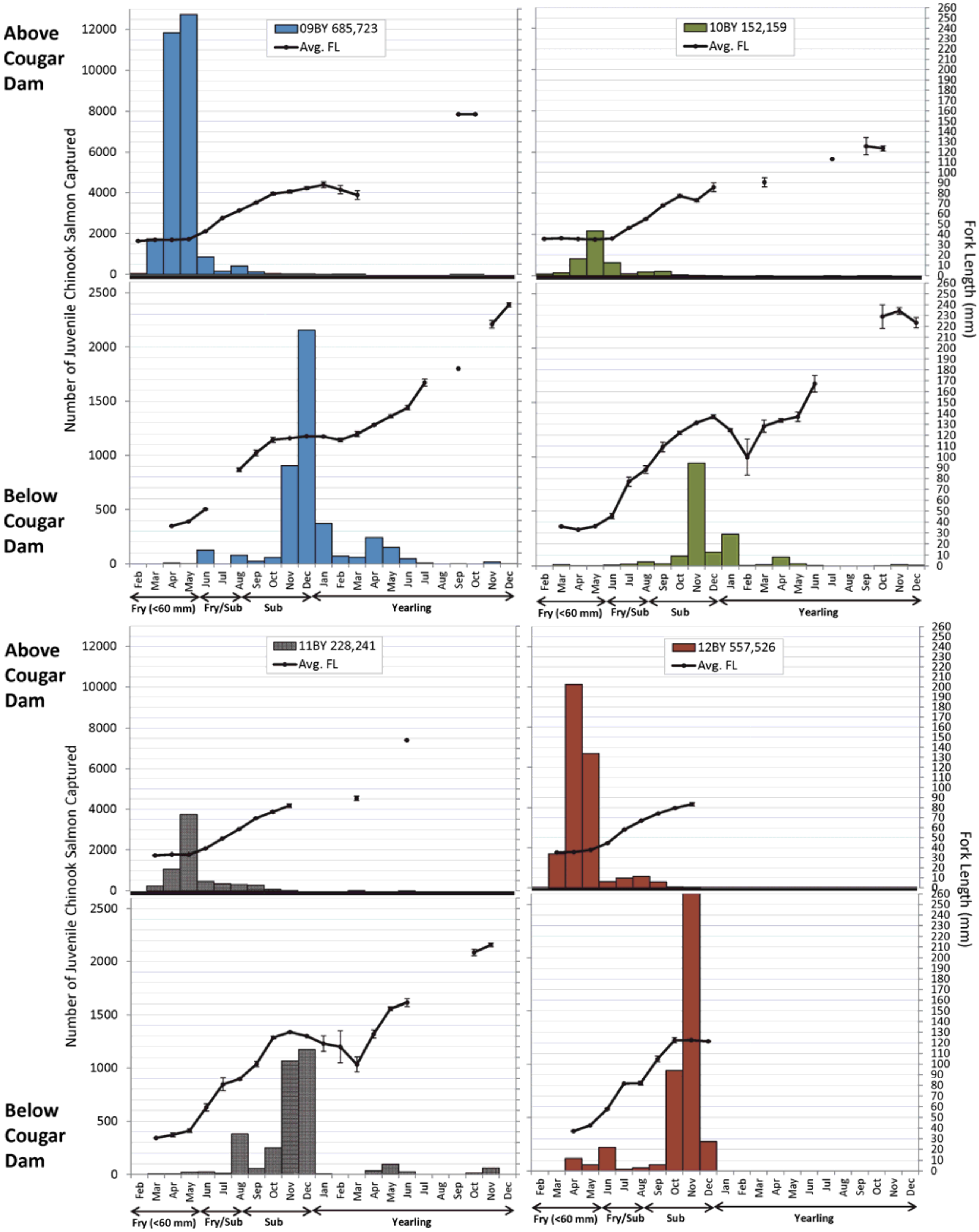

Figure 24. The abundance, average fork length, and timing of Chinook salmon captured for brood years 2009-2012 above and below Cougar Dam, over 22 months. Data are summarized by month and arrows below the x-axis indicate the life stage of juvenile Chinook salmon. Legend includes the estimated number of juvenile Chinook salmon that moved past our upstream screw-trap prior to entering Cougar Reservoir for each BY.*The 2012 BY is incomplete; data were only available through December 2013.

Abundance Estimates of Outmigrants

The South Fork McKenzie trap upstream of Cougar Reservoir – The South Fork McKenzie trap was the only upstream trapping site where we captured sufficient numbers of fish to provide a robust abundance estimate. Weekly trap efficiencies ranged from 1.7 to 17.6% with a weighted annual TE of 3.8 % for 2013. We estimated 557,526 (95% CI ± 66,031) subyearlings (2012 BY) migrated past our screw trap and into Cougar Reservoir between January and December 2013. This was the highest abundance estimate since the 2009 BY and more than double the estimate from last year (2011 BY). The vast majority (94%) of subyearlings moved into Cougar Reservoir as fry from March through May. The initial pulse of fry movement we observed during the peak of the fry migration appeared to be related to stream flow in the South Fork McKenzie (USGS gauging station 14159200 near Rainbow; Figure 25). A similar number of redds were counted during spawning ground surveys for brood years 2011 and 2012 but there were 112 more adult females transported upstream of Cougar Dam in 2012 BY(Sharpe et al. 2013; Table 2).

Recently there has been an increase in the number of redds observed downstream of the South Fork McKenzie screw trap (Table 2). Progeny from these redds are not included in our abundance estimate, so it is likely that recent abundance estimates were biased low. We do not know the survival rate of the eggs to emergence for these redds near the head of the reservoir, but a contribution of 12% and 13% of the overall redds counted for the 2011 and 2012 BY (respectively) may be significant if the trend persists. For the upcoming 2013 BY the number of redds below the trap were not counted prior to an anomalous high flow event on September 30 (1,390 ft^3/s) near the peak of spring Chinook spawning season which washed away evidence of redds. Therefore, the peak number of redds for the 2013 BY will also likely be an underestimate.

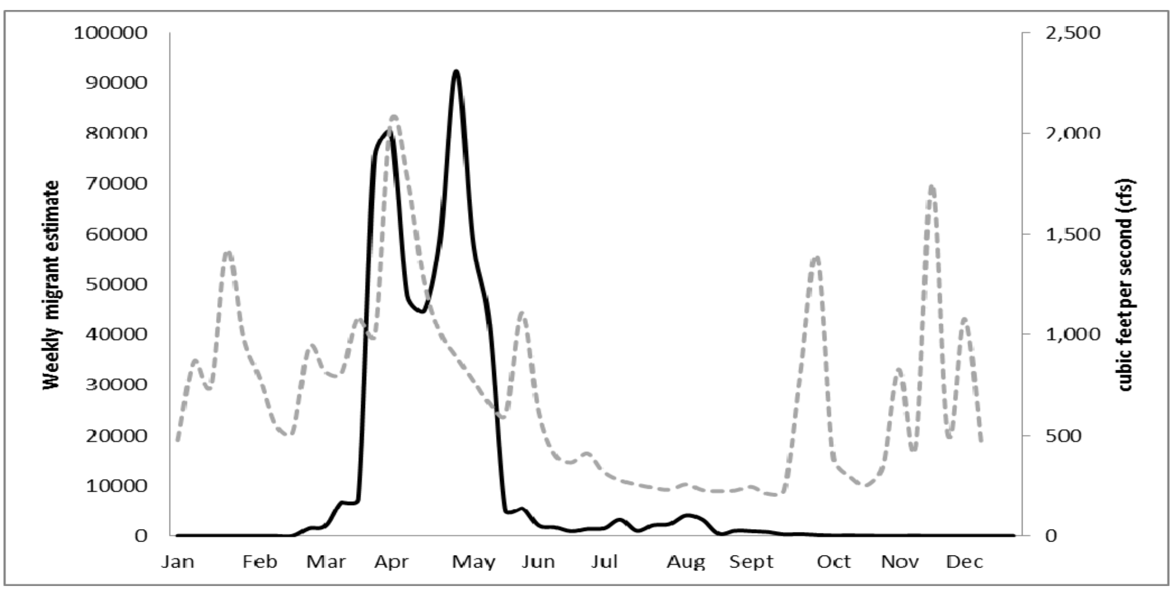

Figure 25. The estimated number of subyearling spring Chinook salmon migrating past the South Fork McKenzie trap and maximum flow level in 2013, summarized by week. Estimated number of subyearlings is represented by the solid black line and corresponding flow is represented by the dotted grey line.

Table 2. Annual estimates of the number of juvenile Chinook salmon migrating past the South Fork McKenzie screw trap upstream of Cougar Reservoir. Female and redd data from Sharpe et al. (2013).

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

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 2.8 to 17.1 % with a weighted annual TE of 4.9% for the two turbine tailrace traps (acting as a single unit). Efficiencies for the trap in the regulating outlet ranged from 3.0 to 4.5 % with a weighted annual TE of 3.7%. We estimated that 55,335 (95% CI ± 11,879) live subyearling Chinook (2012 BY) exited Cougar dam through the turbines, and 32,370 (95% CI ± 22,285) passed using the regulating outlet in 2013. Using the 2013 weighted yearly trap efficiencies for each of the routes and catch information through April 23, 2014, we estimated that an additional 6,490 (95% CI ± 1,370) yearlings from the 2012 BY exited through the turbines, and 3,433 (95% CI ± 2,564) from the regulating outlet in spring 2014. From previous data, we would suspect that most of the yearlings from the 2012 BY had passed the dam by the end of April 2014 (Figure 24).

Although confidence intervals show that our estimates lack a high degree of precision, the South Fork McKenzie is the first 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. In the tailrace, the two highest weekly estimates of the number of fish passing the traps below the dam correspond to an increased number of fish captured in the traps (which would be expected), and decreased trap efficiency estimates (which seems peculiar but may be accurate). It is also possible that during periods when large numbers of fish are captured and processed, not all marked TE fish were properly identified due to small size of fry and small clips taken, thus violating one of the major assumptions of any capture- mark-recapture estimate. This would decrease the TE, and cause and overestimate in the number of fish passing during that period. It should also be noted that fish released for TE estimates 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.

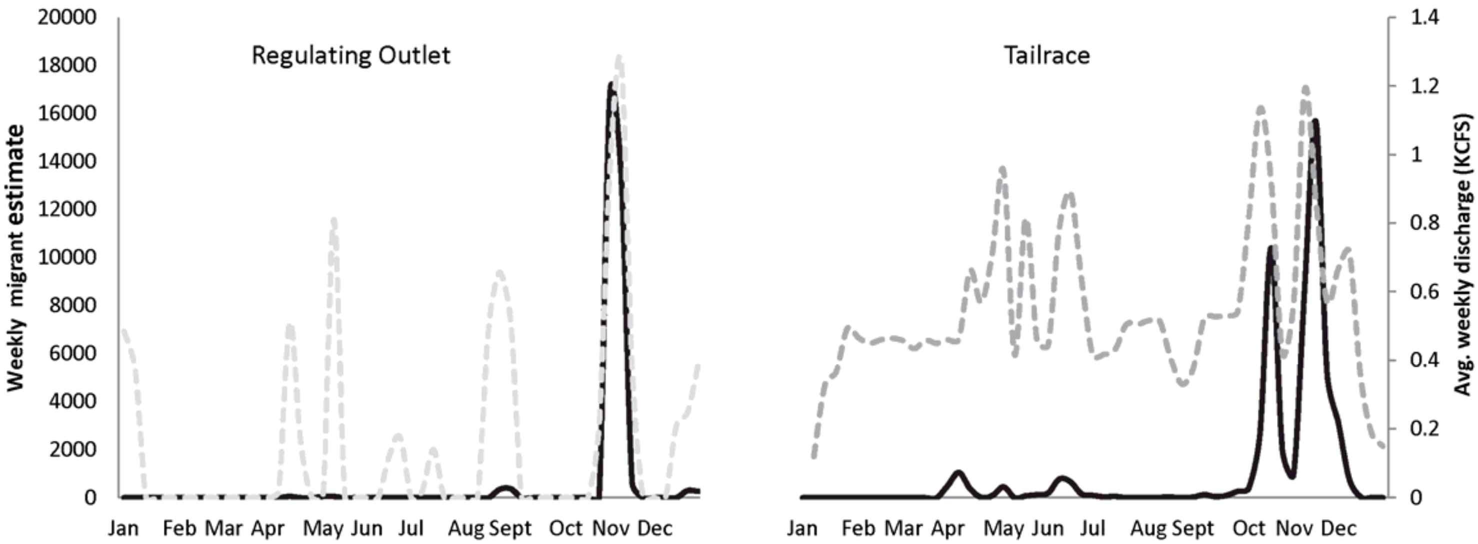

Figure 26. Estimated number of live subyearling spring Chinook salmon migrating past Cougar Dam and discharge in 2013, summarized by week.

We estimated 97,628 (95% CI ± 25,420) juvenile Chinook salmon from the 2012 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 species of any of the reservoirs we sampled in the upper Willamette basin (Lookout Point, Foster, 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. 2014). Using the above and below dam estimates, we conclude ~17.5% (11.6 – 25.0%) of the Chinook salmon migrating past the screw trap upstream of Cougar Reservoir in 2013 (2012 BY) survived to below Cougar Dam.

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 (n=33) but that production would be included in estimates below the dam. Second, we believe the estimate below the dam is potentially overestimated by as much as 25,000 because, as previously mentioned, trap efficiencies during periods of high catch were peculiarly low. Given these potential biases, the lower end of the 95% confidence interval for the percent surviving reservoir rearing and dam passage (11.6%) may reflect a more accurate estimate. We plan to refine our trap efficiency estimates in relation to discharge which should improve our below dam estimates.

Finally, our estimate of 17.5% total project survival should not be confused with fry-to-smolt survival estimates, which have been estimated at 10.1% for Chinook salmon, but are known to vary among populations (Quinn 2005). Reasons that estimates for project survival cannot be compared to fry to smolt survival include 1) our data are collected throughout the year and juvenile Chinook begin passing the dam as fry typically in April, and 2) a majority of fish from any given brood year pass the dam in the fall as subyearlings, and whether or not those fish are "smolts" is unknown.

Recommended Future Directions

Our data provides evidence to suggest that subyearling Chinook and *O. mykiss* are the prominent year class emigrating from streams into WVP reservoirs. These fish grow larger and more quickly in the reservoirs, which could result in increased survival to adulthood (Claiborne et al. 2011; ISRP 2011). However, any benefits of rearing in reservoirs by salmonids must be weighed against potential risks to recruitment to the ocean, such as residualism and larger individuals incurring higher mortality when passing through dams (Taylor 2000; Normandeau 2010; Keefer et al. 2011; Zymonas et al. 2012 *in review*). Juveniles that rear in a reservoir are also exposed to predation and copepod infections (Monzyk et al. 2012, 2013, 2014), though the exact effects of these risks have not been fully assessed. Management strategies aimed at providing safe passage through reservoirs and dams for earlier life-stages, including at-dam passage structures and interim dam operations will help maintain diverse life-history strategies, specifically for those that reach the Columbia River estuary in the spring as subyearlings (Mattson 1962; Schroeder et al. 2007, 2013).

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 (e.g., Cougar Reservoir delays migration ~5 months; Figure 4). We suggest facilitating sub-basin specific outmigration through operations such as delayed refill in the spring where possible. We hypothesize that passing more fish at a smaller size earlier in the year would, in addition to maintaining diverse life-history strategies, also likely improve overall passage survival and help mitigate for the potential risks of copepod infection and predation associated with reservoir rearing until the impact of these risks are better understood. We provide peak migration periods for juvenile salmonids entering each of the reservoirs from 2010-2013 in Appendix B, Table B3.

Fall operations, such as reservoir drawdown, alone or combined with spring operations are likely to produce additional benefits. Retention of juvenile salmon in reservoirs over the summer allows them to reach a larger size prior to operations that allow outmigration, a model that has already been implemented at Fall Creek Reservoir. However, dam operations here are atypical. There are no turbines in Fall Creek Dam for hydropower generation, so there is little need to store water during the winter. In addition, we are unaware of any analyses demonstrating improved smolt-to-adult survival for this system relative to drawdown operations. Complete drawdown may not be a feasible option at many projects.

There was also a deep drawdown implemented at Cougar Reservoir in December 2012. This drawdown may have advanced the dam passage timing of juvenile Chinook salmon by several weeks, although the pattern of emigration from the reservoir remained the same as in previous years with capture numbers declining near the end of December. The low discharge conditions in January 2013, as the reservoir refilled, may have resulted in fewer yearlings outmigrating early and partially explains why we observed yearlings throughout the remainder of the year. It would be useful to attempt deep drawdown earlier in the fall to determine whether large numbers of fish would exit the reservoir, increasing cohort dam passage efficiency and reducing the likelihood of residualism. The need to hold back more water in the reservoir in January to refill the reservoir to pre-drawdown levels may have contributed to fewer yearlings passing the dam in January 2013. An earlier deep drawdown (i.e., November) would allow more time to refill the reservoir. Lower reservoir pool elevation earlier in the year may also decrease the effects of barotrauma for a larger proportion of fish entrained for passage as the elevation change associated with dam passage would be decreased.

We will continue to operate rotary screw traps at the same locations in 2014. Continued monitoring will provide a more complete picture of outmigration both upstream and downstream of WVP dams. Long-term monitoring data generated from this project will allow researchers 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.

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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 2013.

Location	Subyearling	Yearling	Total
SF McKenzie[a]	1,277	10	1,287
Cougar Reservoir	84	0	84
Cougar Tailrace	1	13	14
Breitenbush River[b]	0	0	0
North Santiam River[c]	68	7	75
Detroit Reservoir	0	0	0
Detroit Tailrace	3	0	3
Middle Fork Willamette[d]	83	65	148
NF Middle Fork Willamette[e]	0	0	0
Lookout Point Reservoir	3	0	3
South Santiam River[e]	43	2	45
Foster Reservoir	60	0	60
Foster Tailrace	23	2	25
Total	**1,640**	**99**	**1,739**

[a] 576 of the subyearlings were tagged while seining
[b] No sampling was conducted in the Breitenbush in 2013
[c] One hatchery CHS was tagged, not included in table
[d] Two 2+ aged fish tagged, not included in table
[e] Eight subyearlings were tagged while seining

Table A2. Number of juvenile Chinook salmon PIT-tagged in screw traps and reservoirs by the Willamette Reservoir Research Project, 2010-2013.

Location	2010	2011	2012	2013	Total
South Fk. McKenzie R.	83	615	897	1,287	2,882
Cougar Reservoir	440	547	537	84	1,608
Cougar Tailrace	--	1,072	308	14	1,394
Breitenbush R.	8	111	--	--	119
North Santiam R.	231	184	25	76	516
Detroit Reservoir	--	58	--	--	58
Detroit Tailrace	--	66	7	3	76
Middle Fk. Willamette	76	36	36	148	296
NFMF Willamette	109	78	177	--	364
Lookout Point Reservoir	83	72	1	5	161
South Santiam R.	67	1	12	45	125
Foster Reservoir	--	--	--	60	60
Foster Tailrace	--	2	4	25	31
Total	**1,097**	**2,842**	**2,004**	**1,747**	**7,685**

Table A3. Number of juvenile *O. mykiss* PIT-tagged by the Willamette Reservoir Research Project in the South Santiam sub-basin, 2011-2013.

Location	2011	2012	2013	Total
South Santiam	205	321	361	887
Foster Reservoir	--	--	430	430
Foster Tailrace	--	49	9	58
Total	**205**	**370**	**800**	**1,375**

Table A4. Juvenile Chinook salmon PIT-tagged above and below Willamette Valley Projects 2010-2013 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 was tagged. Fish detected and recaptured at Leaburg were only counted one time.

Tagging Location	Recap/Interrogation Location (RKM)	Number Recaptured 2010	2011	2012	2013
North Santiam River	Willamette Falls	3	2	0	0
	Columbia River Trawl	1	0	0	0
Breitenbush River	Willamette Falls	0	2	--	--
Detroit Reservoir	Willamette Falls	0	1	0	0
Detroit Tailrace	Willamette Falls	0	1	0	0
South Santiam River	Willamette Falls	4	0	0	1
Foster Reservoir	Willamette Falls	--	--	--	1
Foster Tailrace	Willamette Falls	--	--	0	4
SF McKenzie River	Cougar Reservoir	0	4	0	0
	Cougar Tailrace	0	10	14	14
	Leaburg	0	15	23	32
	Walterville	--	0	19	14
	Willamette R3 (175-301)	0	0	1	0
	Willamette Falls	0	2	10	1
	Columbia River Trawl	0	1	0	0
Cougar Reservoir	Cougar Reservoir	2	6	9	0
	Cougar Tailrace	5	5	8	1
	Leaburg	23	5	14	5
	Walterville	--	2	9	2
	Willamette Falls	3	2	3	2
Cougar Tailrace	Leaburg	0	204	51	5
	Walterville	0	23	3	4
	Willamette Falls	0	12	4	1
	Columbia River Trawl	0	1	0	0
	East Sand Island	0	0	1	0
NFMF Willamette River	Willamette Falls	--	1	2	--
	Columbia River Trawl	--	0	1	--
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
	East Sand Island	1	0	0	0
Lookout Point Reservoir	Willamette Falls	1	0	0	0

Appendix B. Basin-wide information.

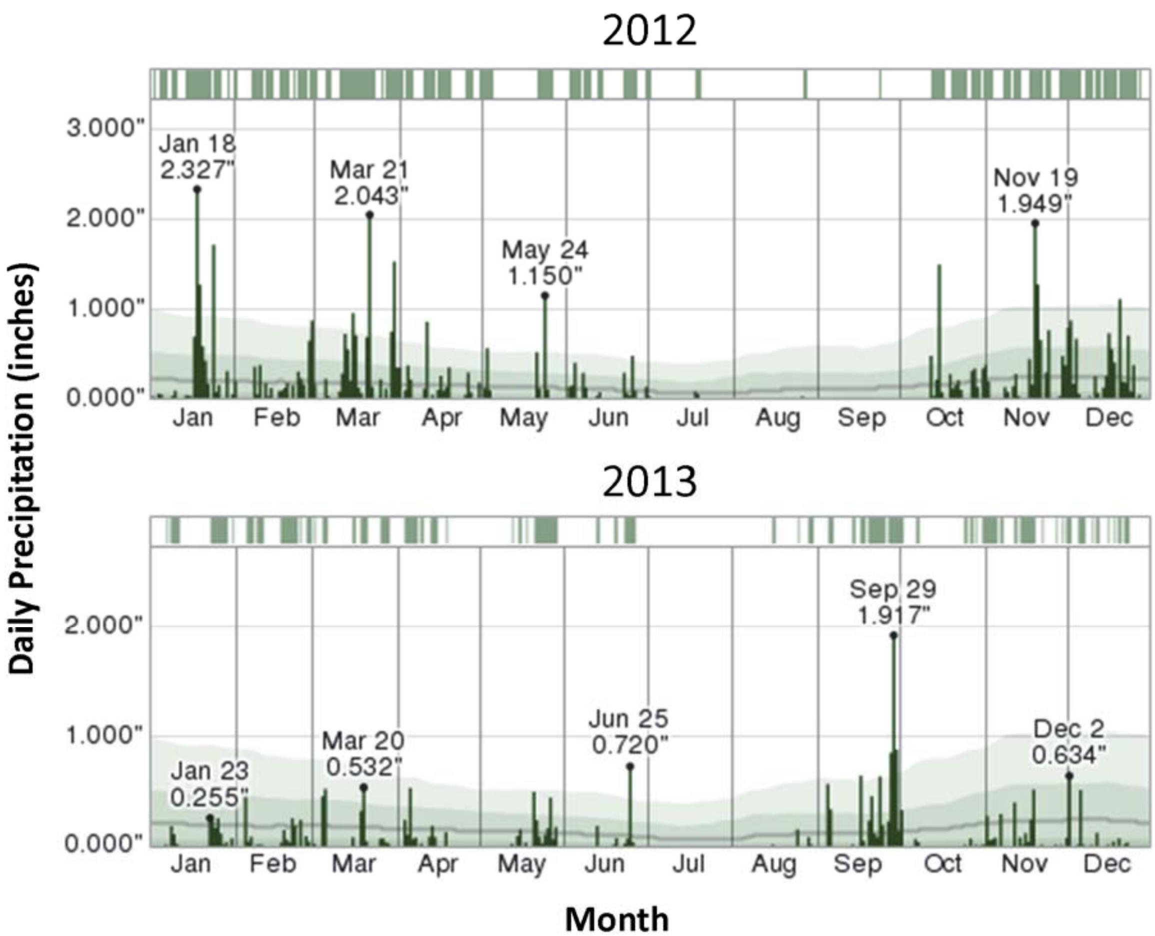

Figure B1. The daily measured quantity of liquid (or liquid equivalent in the case of solid precipitation) precipitation during 2012 and 2013, with the median non-zero quantity (thick grey line) and 10th, 25th, 75th, and 90th non-zero percentiles (shaded areas). The bar at the top of the graph is green if any precipitation was measured that day and white otherwise. Graphs were obtained from http://weatherspark.com/history/30206/2012/Eugene-Oregon-United-States and are for comparative purposes only.

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

Reservoir	River	Brood Year	♀ Outplants
Detroit	Breitenbush	2009	36
		2010	397
		2011	0
		2012*	23
		2013*	144
	North Santiam	2009	111
		2010	746
		2011	63
		2012	98
		2013	540
Foster	South Santiam	2009	172
		2010	231
		2011	597
		2012	444
		2013	428
Cougar	South Fork McKenzie	2009	629
		2010	320
		2011	336
		2012	448
		2013	337
Lookout Point	North Fork Middle Fork Willamette	2009	361
		2010	573
		2011	787
		2012	1,208
		2013	931

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

	Median Migration Date			
Location	2010	2011	2012	2013
North Santiam	-	May 6	May 14	May 14
Breitenbush	-	Mar 8	-	-
South Santiam	-	-	Mar 7	Feb 28
South Fork McKenzie	May 1	May 16	May 16	Apr 26
Middle Fk. Willamette	-	Mar 28	Apr 13	Apr 4

Table B3. Peak months of juvenile steelhead and subyearling spring Chinook salmon migration into reservoirs in all rivers with rotary screw traps (2010-2013).

River	Peak months of subyearling migration	Species
North Santiam	March - June	Spring Chinook salmon
Breitenbush[1]	February - April	Spring Chinook salmon
South Santiam[2]	February - March	Spring Chinook salmon
	July – November[3]	Winter Steelhead
Middle Fork Willamette	February - June	Spring Chinook salmon
South Fork McKenzie	March - June	Spring Chinook salmon

[1] Based on one year of screw trap data (2011)
[2] South Santiam is currently the only river where wild winter steelhead are present
[3] Includes all age-classes

Appendix C. Below Cougar Dam.

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

Life Stage	Month	2009 BY	2010 BY	2011 BY	2012 BY
Fry (< 60 mm)	Mar	0	13	6	0
Fry (< 60 mm)	Apr	9	1	6	118
Fry (< 60 mm)	May	1	1	23	60
Fry/Subyearling	Jun	127	9	25	218
Fry/Subyearling	Jul	0	17	12	20
Fry/Subyearling	Aug	80	38	380	31
Subyearling	Sep	26	19	60	60
Subyearling	Oct	60	90	250	940
Subyearling	Nov	905	942	1,068	2,605
Subyearling	Dec	2,155	125	1,174	272*
Yearling	Jan	373	288	6	
Yearling	Feb	72	4	2	
Yearling	Mar	62	12	2	
Yearling	Apr	242	82	35	
Yearling	May	153	20	96	
Yearling	Jun	48	5	26	
Yearling	Jul	10	0	0	
Yearling	Aug	0	0	0	
Yearling	Sep	1	0	0	
Yearling	Oct	0	2	15	
Yearling	Nov	17	13	62	
Yearling	Dec	2	6	0	
	Total	4,343	1,687	3,248	4,324

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 Detroit Dam by species and month, 2013. Mysis shrimp counts are estimates. Mk = fin-marked; Unmk = unmarked.

Month	Chinook		Rainbow Trout		Kokanee	Mountain Whitefish	Dace	Pumpkinseed & Bluegill	Mysis Shrimp
	Mk	Unmk	Mk	Unmk					
JAN	5	4	2	3	318	1	0	2	100
FEB	2	0	0	0	10	0	0	0	
MAR	0	2	0	0	95	1	1	1	4,200
APR	0	7	0	1	23	0	20	12	2,100
MAY	26	11	10	7	11	0	4	6	200
JUN	0	27	5	0	30	0	0	1	
JUL	14	11	0	4	7	0	0	0	
AUG	0	3	0	2	7	2	0	12	1,300
SEPT	0	0	1	0	16	0	0	59	1,600
OCT	4	10	0	0	132	0	0	9,257	4,300
NOV	107	113	0	4	369	0	0	2,155	400
DEC	67	57	1	5	55	0	0	1	5,000
TOTAL	225	245	19	26	1,073	4	25	11,506	19,200

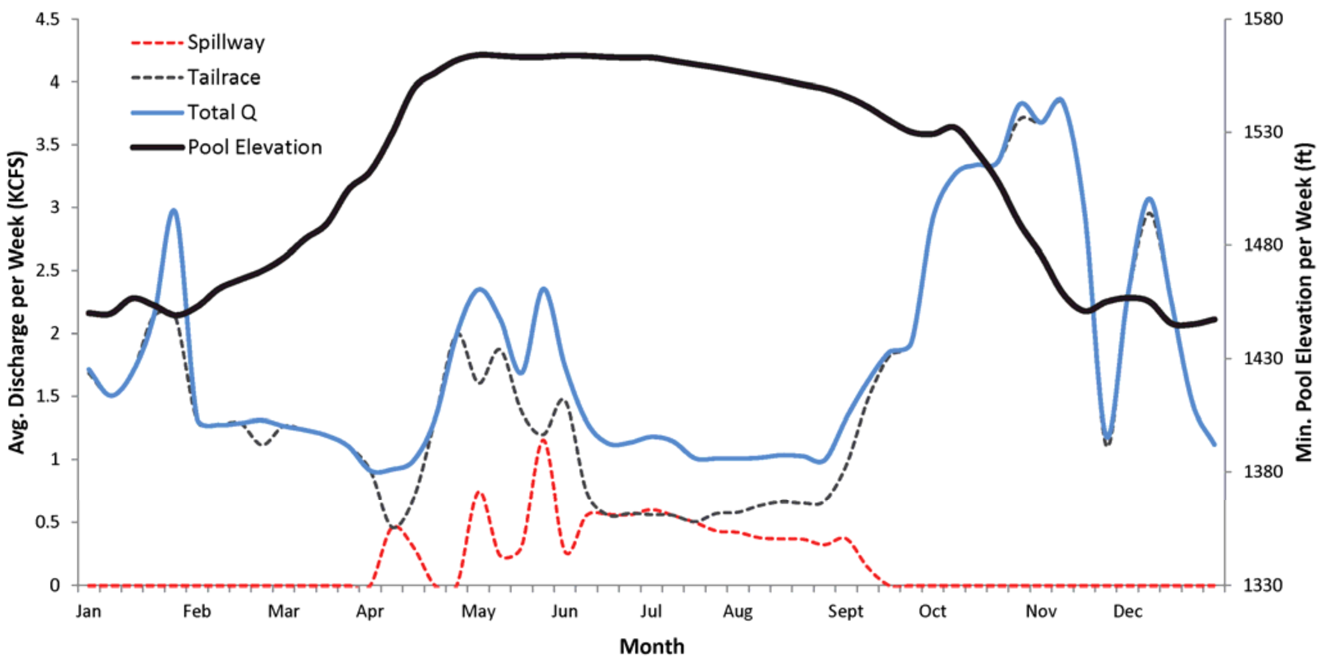

Figure D1. Detroit Dam discharge (Q) and reservoir pool elevation, 2013. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.

Table D2. Number of each species captured in the screw trap below Foster Dam summarized by species and month, 2013. Mk = fin-marked; Unmk = unmarked.

Month	Chinook Mk	Chinook Unmk	*O. mykiss* Mk	*O. mykiss* Unmk	Kokanee	Cutthroat	Yellow Perch	Bluegill	Crappie	Largescale Sucker	Dace	Northern Pikeminnow	Brook Lamprey	Redside Shiner
JAN	0	0	1	0	0	0	16	0	0	0	0	0	0	0
FEB	32	22	0	2	0	0	79	1	0	0	1	0	3	0
MAR	17	97	0	1	0	0	29	1	1	0	0	0	1	0
APR	2	5	9	4	9	0	18	1	0	1	1	0	1	0
MAY	0	3	14	0	7	0	10	0	0	0	1	0	0	0
JUN	0	26	6	3	2	0	2	0	0	1	1	1	0	0
JUL	0	7	7	1	0	0	1	0	0	0	2	0	0	0
AUG	1	0	1	0	0	1	0	0	0	0	0	1	0	0
SEPT	0	4	2	0	1	0	28	0	0	0	0	0	0	0
OCT	0	3	0	20	8	0	172	0	0	4	0	3	0	1
NOV	2	0	8	2	9	1	288	1	0	1	4	0	0	0
DEC	0	0	2	5	33	0	109	0	0	0	0	0	0	0
TOTAL	54	167	50	38	69	2	752	4	1	7	10	5	5	1

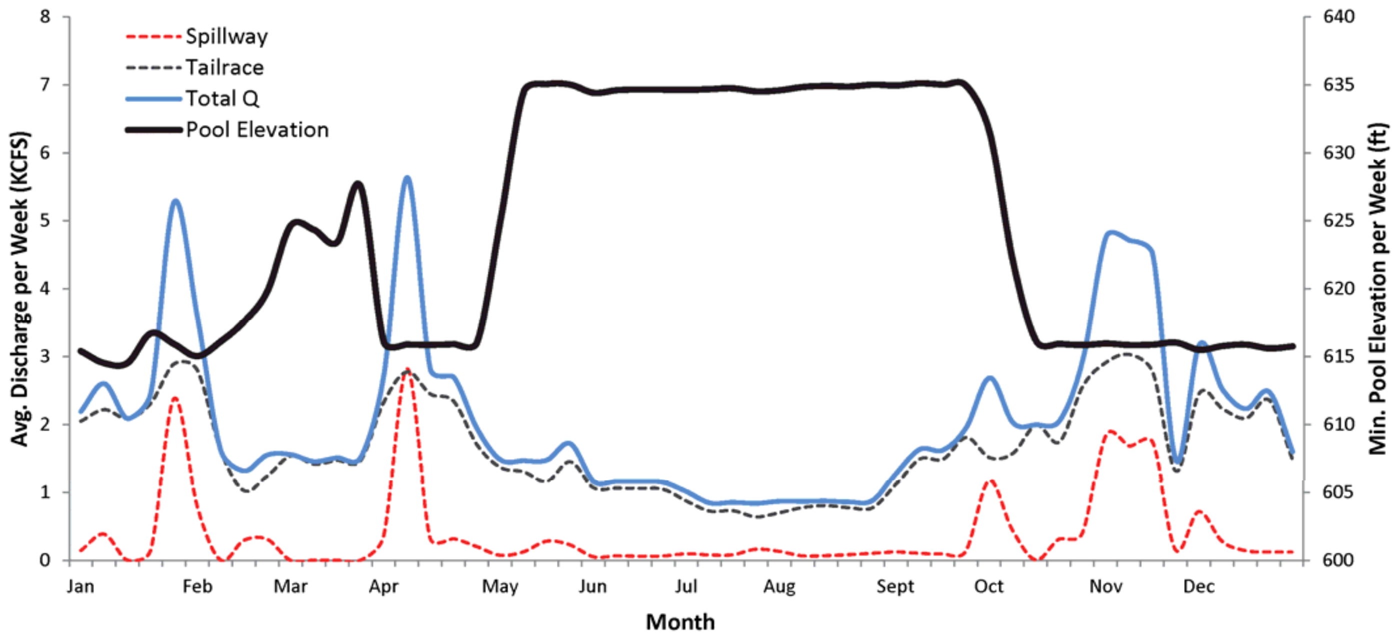

Figure D2. Foster Dam discharge (Q) and reservoir pool elevation, 2013. Discharge is reported as the weekly average and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.

Table D3. Number of each species captured in the screw trap below Lookout Point Dam summarized by species and month, 2013. Mk = fin-marked; Unmk = unmarked.

Month	Chinook Mk	Chinook Unmk	Northern Pikeminnow	Bass	Crappie	Pumpkinseed & Bluegill	Sculpin	Largescale Sucker
JAN	1	0	0	0	0	0	0	0
FEB	0	5	0	0	3	0	5	0
MAR	0	1	0	1	0	0	0	0
APR	0	0	0	0	0	0	0	0
MAY	14	10	0	0	0	0	1	1
JUN	16	4	0	0	0	0	0	0
JUL	3	0	1	0	0	0	6	0
AUG	0	0	0	0	0	0	0	0
SEPT	0	0	0	0	0	0	0	0
OCT	0	0	0	0	2	0	0	0
NOV	3	7	0	0	5	9	2	3
DEC	0	4	0	0	1	0	3	0
TOTAL	37	31	1	1	11	9	17	4

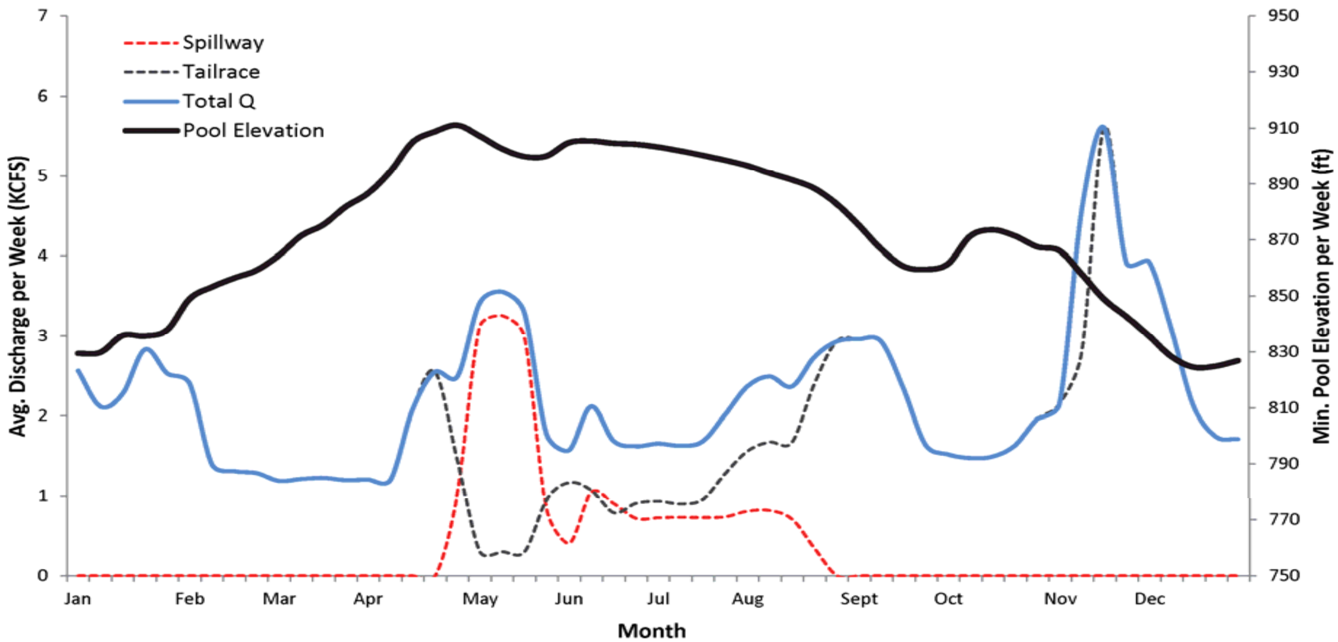

Figure D3. Lookout Point Dam discharge (Q) and reservoir pool elevation, 2013. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week.

Table D4. Number of each species captured in the screw trap below Cougar Dam summarized by species and month, 2013. All Chinook salmon and rainbow trout were unmarked.

Month	Chinook	Rainbow Trout	Cutthroat	Trout Fry	Bull Trout	Mountain Whitefish	Dace	Brook Lamprey	Sculpin
JAN	6	6	0	0	0	3	1	0	2
FEB	2	2	0	0	0	0	0	0	1
MAR	4	12	0	0	1	0	0	0	0
APR	157	25	3	0	0	0	1	0	2
MAY	150	3	1	7	0	0	17	0	1
JUN	244	2	0	17	0	0	17	1	1
JUL	20	2	1	13	0	0	19	0	10
AUG	31	5	1	0	0	0	10	1	17
SEPT	52	3	0	0	0	0	7	0	2
OCT	981	9	2	0	0	1	0	0	0
NOV	2,647	4	1	0	0	2	102	0	0
DEC	272	0	0	0	0	2	0	0	0
TOTAL	4,566	73	9	37	1	8	174	2	36

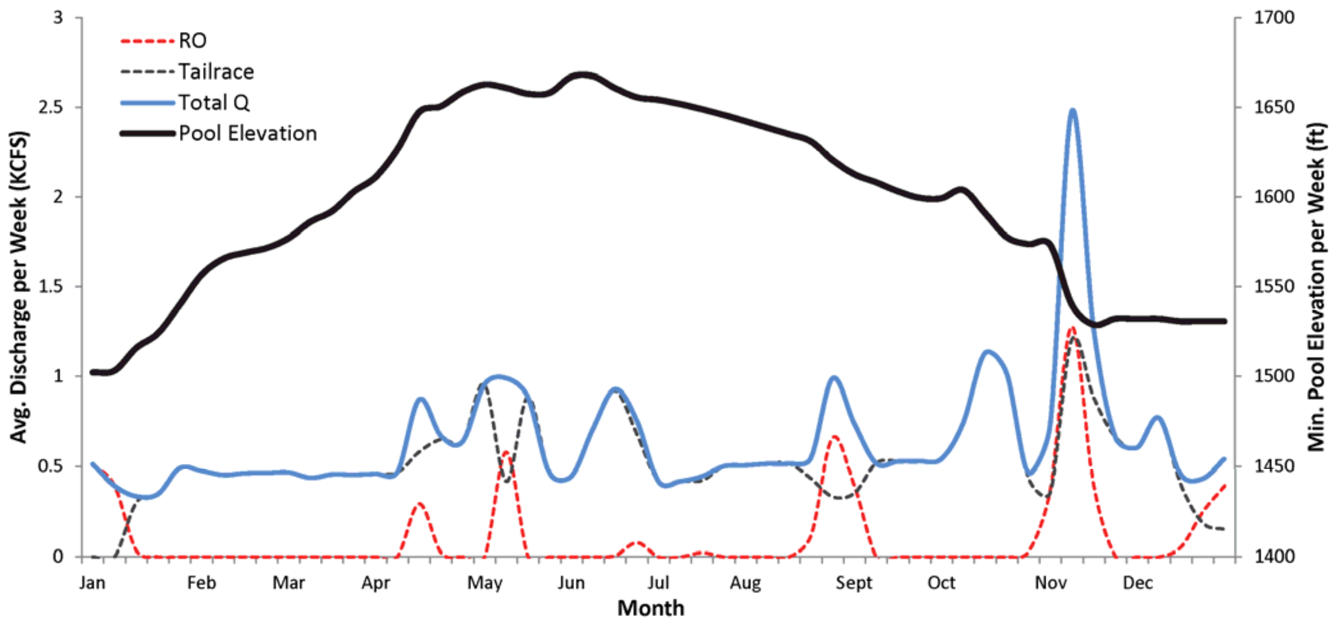

Figure D4. Cougar Dam discharge (Q) and reservoir pool elevation, 2013. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.