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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 regarding fish species composition, timing and size of fish entering and exiting Willamette Valley Project (WVP) reservoirs. This information can be used to evaluate options for development of 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 2014. 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/Big Cliff, Foster, Cougar, and Lookout Point dams (Figure 2).

The objectives of this project were to 1) provide information on migration timing of juvenile spring Chinook salmon *O. tshawytscha* and winter steelhead *O. mykiss* into Willamette Valley Project (WVP) reservoirs; 2) 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) 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 2014, 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. Traps were operated throughout the calendar year until removal in late November or early December in anticipation of high stream flows. 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 directly below dams as ‘discharge’ where it is regulated by dam operations.

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 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 fall 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 South Fork McKenzie and North Santiam rivers has remained similar in since 2011, and in 2014 the median migration date for both sub-basins was May 8. In the South Santiam River above Foster Reservoir our trap was not running for 26 days during what had been the peak outmigration period in previous years. Therefore, we were unable to determine the median migration date on the South Santiam River. 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 9.

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.

Data collected from trapping below dams indicate 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 2014. However, most Chinook salmon 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 – December), in conjunction with reservoir drawdown and lowered pool elevation.

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 primarily in late October; migration timing atypical of what we have previously observed. 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 835 juvenile *O. mykiss* in the screw trap, and PIT-tagged 1,647 (using various methods of capture) upstream of Foster Reservoir in 2014. Age estimates were based on differences in fork length among cohorts.

The migration timing and size of 2013 brood year (BY) spring Chinook salmon in the South Fork McKenzie River was similar to that observed in previous years. The number of subyearlings moving past our trap into Cougar Reservoir was estimated based on TE estimates ranging from 1.3 to 13.2%, and a yearly weighted TE of 2.8%. 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 River we captured 11,402 subyearling Chinook salmon, and estimated that 415,741 (95% CI \pm 56,164) subyearlings migrated past our trap. In 2014 the majority (91%) of subyearlings moved into Cougar Reservoir as fry from March - May.

Introduction

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

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

To aid in the development of downstream passage options, we present results from our operation of rotary screw traps in rivers upstream of Detroit, Foster, Cougar and Lookout Point reservoirs, and in the tailraces of Detroit, Big Cliff, Foster, and Cougar dams. We also summarize data collected from traps below Lookout Point 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 primarily progeny from adults that were trapped and hauled upstream of WVP dams. Exceptions may include production from resident rainbow trout, or from adfluvial Chinook salmon adults. Fish collected in the Middle Fork Willamette River trap also included juvenile hatchery Chinook salmon (~20,000 clipped juveniles; Dan Peck ODFW *pers. comm.*) 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 2014–March 2015. Included in this report are a summary and analysis of field activities implemented by ODFW on behalf of the USACE through December 31, 2014, 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 2014 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, which was not deployed in 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, 2014). Traps were operated until removal in late November or December in anticipation of high stream flows, with the exception that the trap in the South Santiam remained in place throughout the calendar year.

The North Santiam trap was located on private property downstream of the Coopers Ridge Road Bridge and was ~5.8 km upstream of Detroit Reservoir (at full pool). The South Santiam trap was also located on private property near the town of Cascadia and was ~10 km upstream of Foster Reservoir (at full pool). The South Fork McKenzie trap was located just downstream from the USGS gauging station (station 14159200) and was ~1 km upstream of Cougar Reservoir (at full pool). The 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 2014 below Detroit, Foster and Cougar dams, and installed a trap below Big Cliff Dam on the North Santiam River (Table 1). We also summarized migrant data received from USACE personnel operating a 2.4-m trap located ~260 m downstream of the base of Lookout Point Dam (Figure 2). Generally, controlled discharge from the dam allowed us to operate traps nearly every day of the year, except for events such as extremely high dam discharge (e.g. the Detroit turbine tailrace in 2014), maintenance, safety upgrades, or when debris or substrate movement prevented the trap from spinning (e.g. the Cougar Dam turbine tailrace in 2013).

At Cougar Dam, juvenile salmonids have two routes by which they can pass through Cougar Dam once they enter the temperature control tower: the turbine penstock (tailrace) or the regulating outlet (RO). The RO and tailrace empty into two separate channels which merge ~100 m downstream of the base of the dam. Our traps were positioned in each channel, enabling us to differentiate catch between the two routes (two 2.4-m diameter traps in the turbine tailrace, one 1.5-m diameter trap in the regulating outlet; Figure 1). The two traps in the tailrace operate side by side (Figure 1) as a single unit. The tailrace traps operated 340 d and the RO operated 326 d (Figure 4).

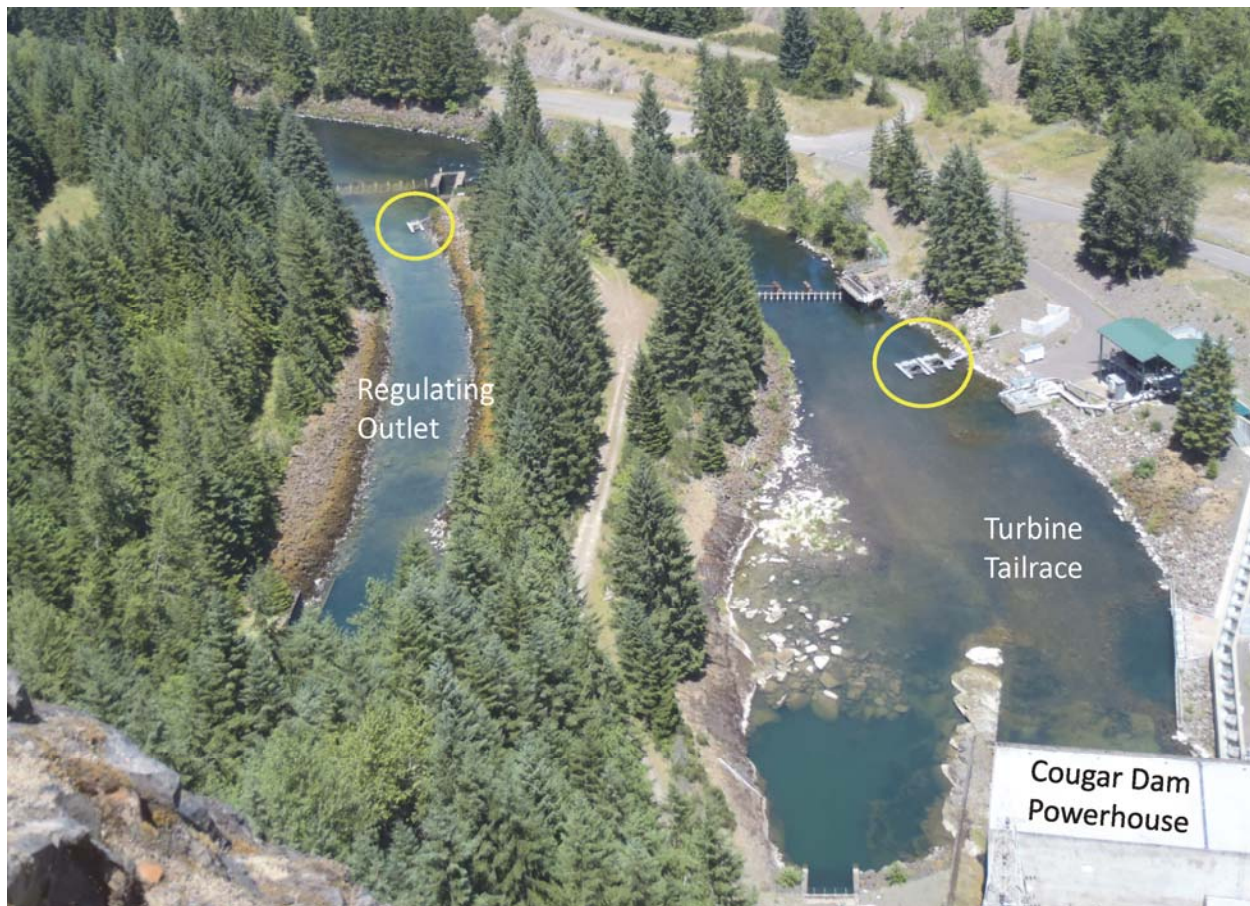


Figure 1. Rotary screw traps below Cougar Dam (1.5 m diameter in regulating outlet, 2.4 m diameter x 2 in tailrace; South Fork McKenzie River rkm 385).

Below Foster Dam, the 2.4-m diameter trap was in the tailrace of the turbine discharge and did not capture fish exiting the reservoir via the spillways. Additionally, the large trap size and the tailrace hydraulic conditions resulted in several periods of low trap rotations (≤ 2 rpm) that likely resulted in low capture efficiency. To improve capture efficiency at the site we added a 1.5-m trap on August 27 to run in tandem with the larger trap (Table 1). This trap was motorized for a portion of its operation to maintain > 4 rpm.

Table 1. Installation dates and location of rotary screw traps above and below Willamette Valley Project reservoirs, 2014. 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	None ^a	286	0568785 4955753
North Santiam	March 19	292	0575240 4949260
South Santiam	January 1	271	0539897 4915479
South Fork McKenzie	February 26	395	0562654 4877522
Middle Fork Willamette	February 27	358	0537699 4846035
Below Dams			
Detroit – Turbine tailrace	April 1	271	0559186 4952388
Big Cliff	March 25	266	0554987 4956117
Foster (2.4 m)	January 1	253	0526128 4917989
Foster (1.5 m)	August 27	253	0526128 4917989
Cougar (all traps)	January 1	385	0560486 4886873
Lookout Point	January 1	333	0519724 4862480

^a Trap not deployed in 2014; no adult fish were outplanted in the Breitenbush River in 2011, 2012, or 2013.

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. In addition to collecting migrant information on spring Chinook salmon, the South Santiam trap (above Foster Dam) was located downstream of most major spawning habitat for adult winter steelhead, which also facilitated collection of migration data for juvenile steelhead.

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

Age estimates of measured juvenile Chinook salmon were quality checked with length-frequency analysis. Juvenile Chinook salmon had a bimodal size distribution with minimal overlap of age classes throughout the year, allowing for delineation of yearlings and subyearlings. We plotted individual fish size by date at each trap and determined juvenile age. Juveniles that hatched in spring 2014 (2013 BY) were classified as subyearlings, and yearlings were fish that hatched the previous year (2012 BY) and remained in the reservoir after January 1,

2014. Salmonids < 60 mm were considered 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; A4) to collect recapture and detection information (Appendix A; Table A3; A5) regarding growth and migration behavior. Growth information can be found in Monzyk et al. (2014, 2015).

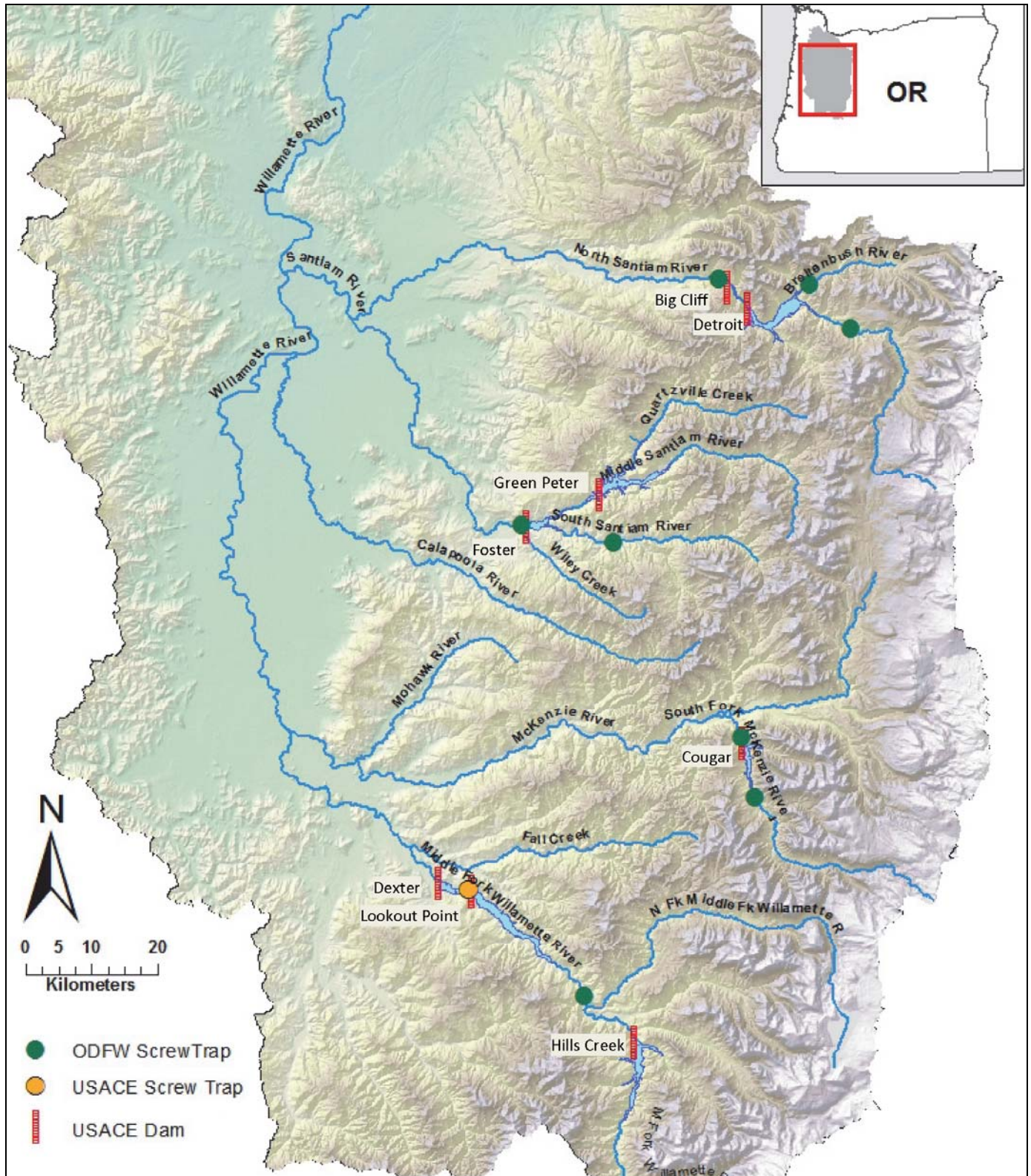


Figure 2. Locations of rotary screw traps operated by the Oregon Department of Fish and Wildlife (ODFW) and USACE above and below Willamette Valley Project dams. The Breitenbush River trap was not operated in 2014.

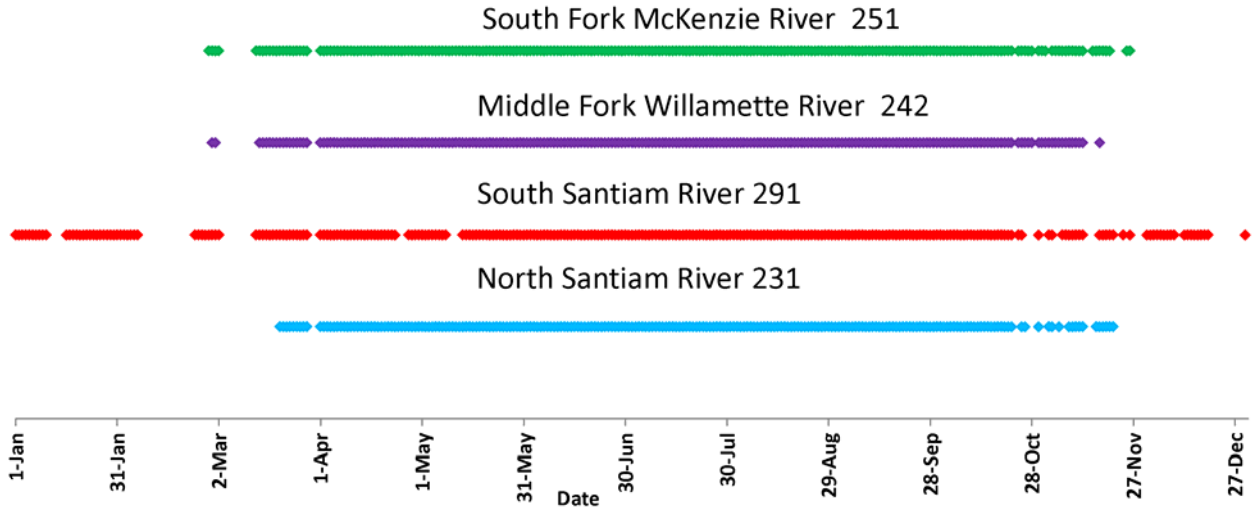


Figure 3. Screw trap operation summary for traps upstream of Willamette Valley reservoirs, 2014. Each colored dot represents one day of operation; numbers are the number of days the trap operated during the calendar year.

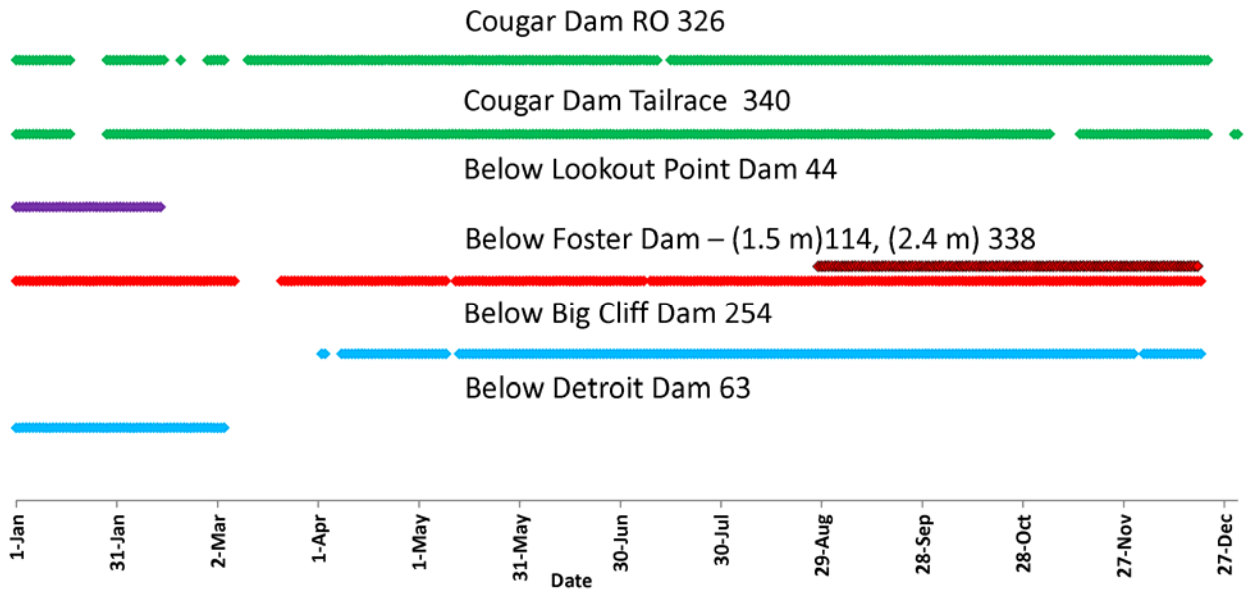


Figure 4. Screw trap operation summary for traps below dams in the upper Willamette River Basin, 2014. Each colored dot represents one day of operation; numbers are the number of days the trap operated during the calendar year. Tailrace = turbine tailrace. RO = regulating outlet. Two traps were operated in tandem below Foster Dam for a portion of the year. Operation of the 1.5 m diameter trap is denoted by the red dots outlined in black.

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 25th and 75th percentiles). Trap efficiency estimates were considered sufficient if more than five marked fish were recaptured per week for at least half of the weeks during the peak migration period. Weekly abundance estimates were summed for yearly totals. During weeks when recaptures were infrequent (< 5 recaptures/week), recapture totals for subsequent weeks were pooled to obtain at least five recaptures. If these criteria were not met for a particular sub-basin, the actual number of 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.

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

The greatest catch of Chinook salmon in traps below Project dams occurred primarily during late fall/early winter during reservoir drawdown and were comprised mainly of subyearlings. There were two exceptions to this pattern. At Foster Dam most Chinook Salmon were typically captured between February and April with a small increase again in June. In recent years (2011 – 2013) below Lookout Point Dam, the greatest catch occurred from May until June, apparently associated with surface spill events, and in 2014 the trap was not operating after February so we were unable to assess migration timing.

North Santiam River- We operated the screw trap in the North Santiam River above Detroit Reservoir from March 19 until December 9, 2014. The trap fished for 231 d and captured 1,151 subyearling Chinook salmon, and four yearlings (Figure 6). The run timing and size of Chinook salmon fry captured in the North Santiam trap were similar to subyearlings observed in the South Fork McKenzie River. The peak migration was from April - May (Figure 5) with a median migration date of May 8 (Appendix B; Table B2). Most subyearlings (73% of our catch) entered Detroit Reservoir during March - May as fry averaging 35 mm FL (Figure 6). Our trap ran intermittently from October – November due to high flows and debris. Similar to 2010 (2009 BY) and 2013 (2012 BY), we observed a smaller pulse of subyearling movement during this period which was not observed in 2011 and 2012 (2010 - 2011 BY; Figure 5). The size range for subyearlings caught throughout the season was 28-141 mm FL.

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

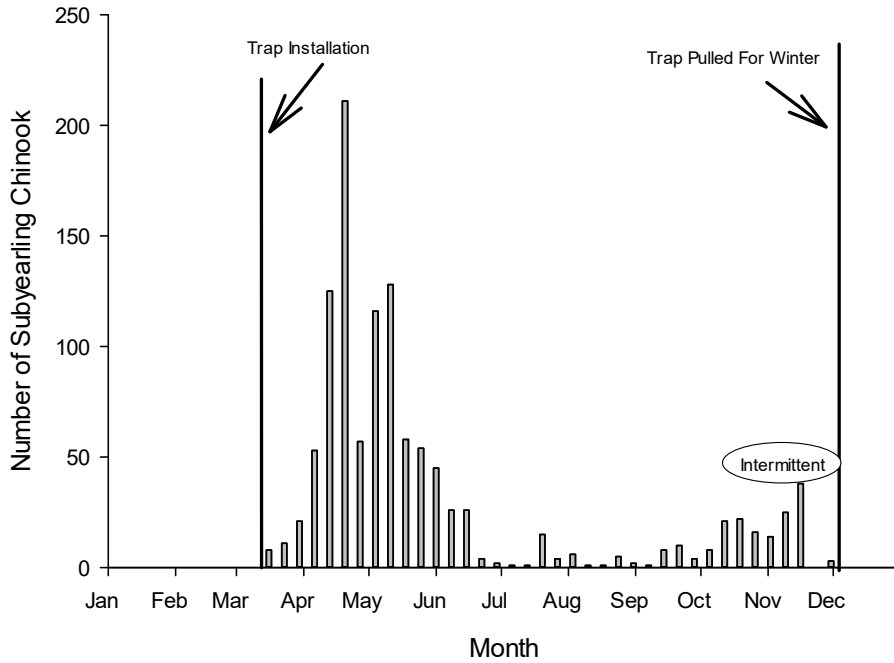


Figure 5. Weekly catch of subyearling spring Chinook salmon captured in the North Santiam trap above Detroit Reservoir, 2014.

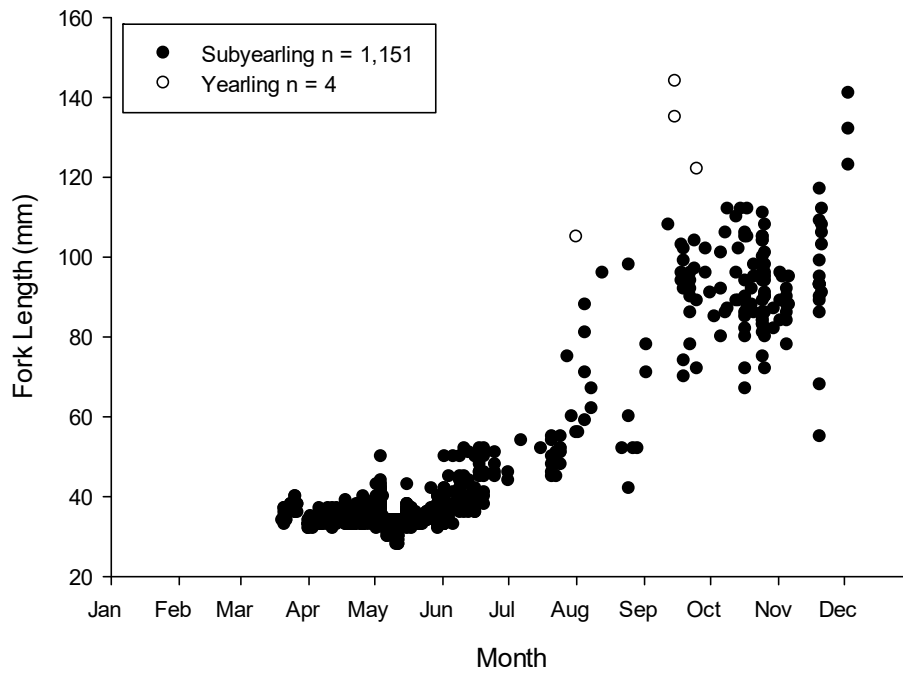


Figure 6. Fork lengths of juvenile Chinook salmon captured in the North Santiam trap above Detroit Reservoir, 2014.

Below Detroit / Big Cliff Dams- The 2.4-m diameter trap located in the tailrace below Detroit operated 63 d in 2014. We captured 49 Chinook salmon and ~1,900 kokanee *O. nerka* in February associated with the increased discharge from turbines and the regulating outlet (RO) (Appendix D, Table D1 and Figure D1). For comparison, only 1,073 kokanee were captured during the entire year of 2013. At the end of February, the trap was badly damaged from increased discharge and was removed on March 6.

On April 1 we installed a 1.5-m diameter trap below Big Cliff Dam to continue migrant data collection from below the Detroit/Big Cliff project. The trap below Big Cliff Dam operated 254 d in 2014. The trap below Big Cliff Dam does not enable us to evaluate migration timing over Detroit Dam, but does provide downstream passage information (migration timing and size of migrants) for the combined Detroit/Big Cliff project. Overall, the outmigration pattern for Chinook salmon appeared similar to previous years trapping below Detroit Dam, with a peak in dam passage at Big Cliff Dam occurring in November - December (Figure 7).

The combined trap catch below Detroit and Big Cliff dams in 2014 was 152 unmarked Chinook salmon, 142 hatchery Chinook salmon, and 2,236 kokanee. Nearly all (97%) of the kokanee were captured below Detroit Dam January 2 - March 4. It is likely that only a small proportion of the kokanee exiting Detroit Dam are available for capture below Big Cliff due to the high mortality for this species observed below Detroit in past years (88, 97 and 98% in 2012, 2013, and 2014 respectively). The hatchery Chinook salmon originated from the release of ~67,000 PIT-tagged fish into Detroit Reservoir (33,485 Detroit forebay, 33,478 head of Detroit Reservoir) on July 9, 2014 (mean FL 74 mm; Brandt et al. 2015 *in review.*).

In April and May we observed higher fish mortality (92% for Chinook salmon) in our screw trap below Big Cliff than observed in our other traps below dams. Several fish captured in the trap (both live and dead) had gas bubbles in their fins, suggesting gas bubble disease. Total dissolved gas (TDG) below Big Cliff Dam averaged 124% (range 117-130%) from April 10 - May 31, as measured at the USGS gauge at Niagara (station 14181500). Super-saturation of dissolved gases was highly correlated with increased spill over Big Cliff Dam (Spearman rank order correlation coefficient 0.84; $P < 0.001$; dam discharge data from USACE website <http://www.nwd-wc.usace.army.mil/cgi-bin/dataquery.pl?k=detroit+dam>). Although we observed high mortality of fish held in the trap, fish that avoided the trap would presumably have higher survival if they are able to move to downstream areas with lower TDG levels.

Mesa et al. (1997) stated that juvenile Chinook salmon confined in water 28 cm deep (similar to the depth of a screw trap live box) at a TDG level of 130% “begin to die after 5 h of exposure, reaching ~ 50% mortality at 9 h”. The authors noted that at 120% TDG in shallow water the mortality rate follows a sigmoid curve reaching about 43% at 58 h. At 120-130% TDG bubbles were present on the lateral line, fins, and gill filaments, but developing slower at lower levels. However, exposure to 110% for 28 d did not cause mortality and resulted in few visible bubbles (Mesa et al. 1997, 2000; Maule et al 1997). We typically held fish in the live box for 12-24 h. Given the high mortality we observed, TDG levels at our trap site may be higher than recorded at the Niagara gauge located 0.8 km downstream. Dam discharge, reservoir elevation and corresponding catch for all species below both dams are summarized by month in Appendix D, Tables D1, D2 and Figures D1, D2 to provide context for fish trapping data. We also include a

figure to illustrate daily total dissolved gas levels below Big Cliff Dam for the year in Appendix D, Figure D3.

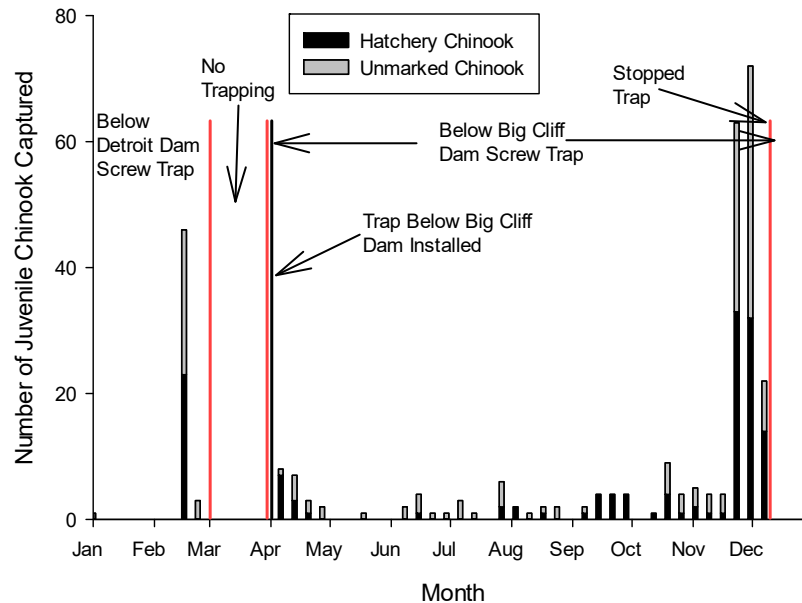


Figure 7. Weekly catch of marked and unmarked Chinook salmon (subyearling and yearlings) captured in the rotary screw traps below Detroit and Big Cliff dams, 2014.

South Santiam River Spring Chinook Salmon- We operated the South Santiam trap upstream of Foster Reservoir from January 1 through December 31, 2014. The trap fished for 291 d and captured 161 subyearlings and no yearlings in 2014. Peak fry movement is typically February – March, but our trap was not operating for 26 d during this period (February 6-21, March 2-11; Figure 8) due to high flow and debris loads, such that we were unable to estimate a median migration date for 2014. The South Santiam River maintained high flows for an extended amount of time, peaking on February 12 at 8,480 ft³/s and again on March 10 at 6,210 ft³/s. We were unable to operate our trap at flows > 1,680 ft³/s.

The South Santiam Chinook salmon emerged earlier than other sub-basins and grew quickly. Those captured in the screw trap upstream of Foster Reservoir were larger in February – March than their stream-rearing counterparts in other sub-basins, likely due to the earlier emergence timing (Figure 18). Emergence timing and growth were most similar to juveniles from the Middle Fork Willamette River. To illustrate the effect of differences in temperature on emergence date among years we estimated the emergence timing for eggs deposited on a standardized date (September 15) for brood years 2010-2014 in Table 2. The starting date for the accumulated thermal unit calculations (ATU; Connor et al. 2003; Geist et al. 2006; Groves et al. 2008) 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). We observed the first 2014 BY Chinook salmon in the South Santiam on December 18, earlier than

in any of the previous trapping seasons which can be explained by the increased stream temperatures during incubation shown in the ATU calculations (Table 2).

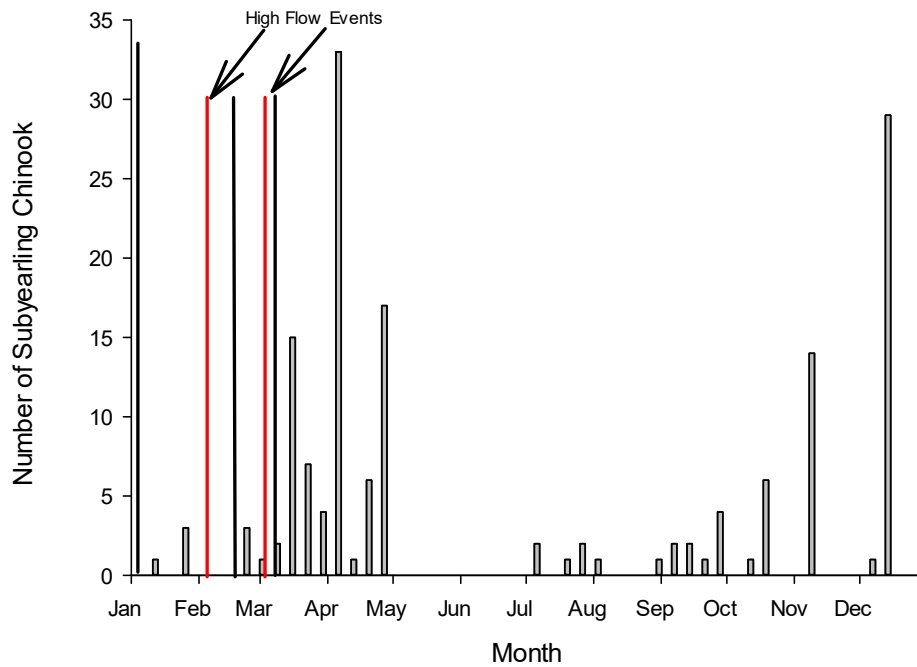


Figure 8. Weekly catch of subyearling spring Chinook salmon captured in the South Santiam trap above Foster Reservoir, 2014. Red vertical lines indicate days when the cone was lifted and the trap was not fishing. Black lines indicate when the cone was lowered and the trap continued fishing unless otherwise noted in the text.

Table 2. Estimated emergence date based on a deposition date of September 15 and date of the first fry captured for spring Chinook salmon (CHS) in the South Santiam River brood years 2010 – 2014. Estimates based on 1,000 accumulated thermal units in degrees Celsius. Mean daily temperatures collected from USGS gaging station 14185000 near the town of Cascadia. Asterisk indicates dates when Chinook salmon were captured the first day of screw trap operation for that trapping season.

Brood Year	Estimated Emergence Date Based on a Deposition Date of	
	September 15	1 st CHS fry captured
2010	January 11, 2011	January 4, 2011*
2011	January 25, 2012	January 6, 2012
2012	January 15, 2013	January 8, 2013*
2013	February 12, 2014	January 18, 2014
2014	December 22, 2014	December 18, 2014

The number of subyearlings captured in 2014 (2013 BY) was 568 less than the previous year even though there were roughly the same number of females released into the South Santiam River in 2012 and 2013 (Appendix B, Table B1). This difference in the number of Chinook

salmon captured is likely due to the period in the early spring when we were unable to operate the trap but may also be attributable to high flows in February that scoured redds.

We suspect that scouring high flows ($>10,000 \text{ ft}^3/\text{s}$) during egg incubation in some years may limit juvenile production in the South Santiam River (Romer et al. 2013). The river above Foster Reservoir has a deeply incised channel and most of the accessible spawning substrate is perched on bedrock. The South Santiam River has been in this condition since the 1930s, according to a Bureau of Fisheries stream habitat report (McIntosh et al. 1990), recently corroborated by a watershed assessment conducted in 2000 (South Santiam Watershed Council 2000) which states that:

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

High flows that occur early in the year may displace redds, causing direct mortality to eggs and alevins residing in the interstitial spaces of the substrate. Peak flows $>10,000 \text{ ft}^3/\text{s}$ have occurred in mid-January (near estimated emergence timing) for three of the five years (2010-2014) that we have assessed juvenile production above Foster Reservoir. Peak flows were $<5000 \text{ ft}^3/\text{s}$ in 2010 (BY2009) and 2013 (BY2012) and the year-class strength of returning adults from those brood years compared to other years may lend insight to the quality of spawning habitat above Foster Reservoir and its effect on juvenile production.

Historically, 85% of the spring Chinook salmon production in the South Santiam system occurred above Foster Dam (Mattson 1948 *as cited in* Wevers et al. 1992). Prior to the construction of Green Peter Dam (1967) on the Middle Santiam River and Foster Dam (1968) on the South Santiam River, the primary 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 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 production in the South Santiam system.

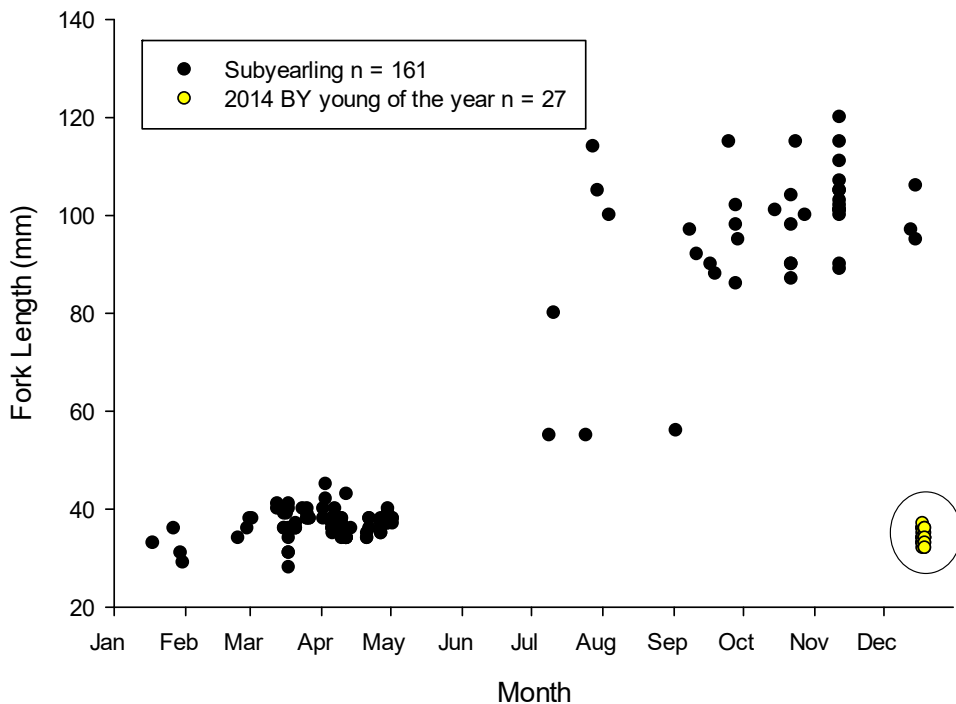


Figure 9. Fork length of subyearling and yearling Chinook salmon collected in the South Santiam trap above Foster Reservoir, 2014. Circle indicates 2014 BY young of the year. No yearling Chinook salmon were captured in this trap in 2014.

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*. Juvenile *O. mykiss* captured in our trap were a mixture of steelhead and rainbow trout, but we presume that most are the progeny of adult steelhead due to the large number of adults transported upstream of Foster Reservoir. For comparison, in the South Fork McKenzie River where resident rainbow trout are present but steelhead are not, we captured 83 rainbow trout, 24 cutthroat trout and 123 trout fry (a mix of cutthroat and rainbow trout). We captured 835 juvenile *O. mykiss* in the South Santiam screw trap in 2014 and based on length-frequency distributions there were at least three distinct year classes present. The subyearling cohort reached a maximum FL of ~100 mm and comprised 72% of the total *O. mykiss* catch for the year, similar to the 77% of total catch in 2013. The age-1 and age-2 juveniles ranged in size from ~100-200 mm FL (Figure 10).

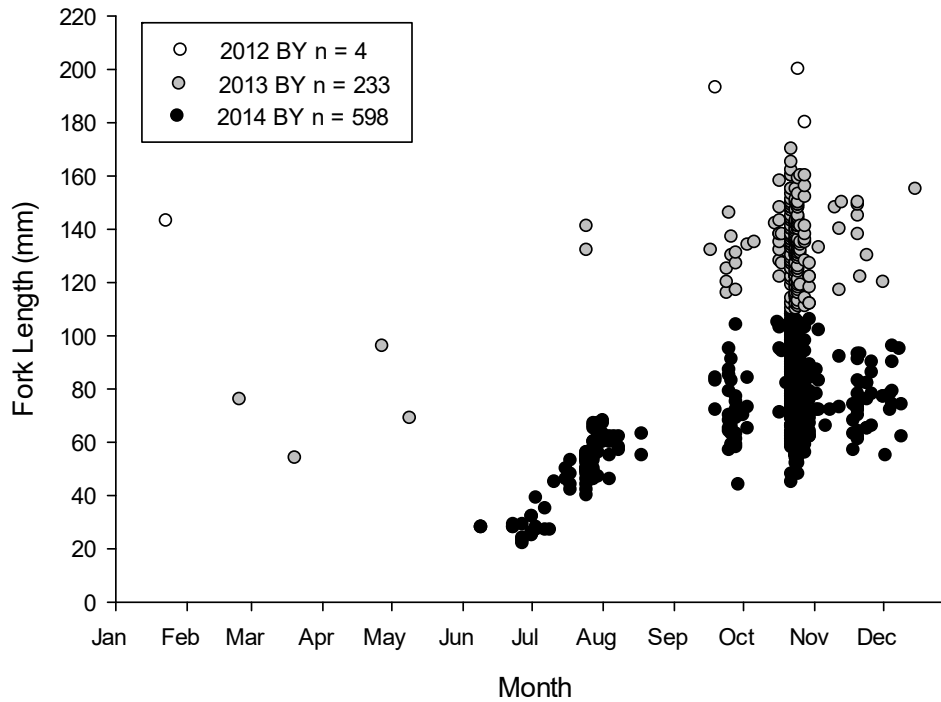


Figure 10. Fork lengths of *O. mykiss* caught in the South Santiam trap above Foster Reservoir, 2014.

The first subyearlings are usually captured in mid to late June, and they continue to emigrate from the river into Foster Reservoir until the end of November. In 2014, peak migration occurred in October when we captured 77% of our total *O. mykiss* catch for the year (644/835; Figure 11). This movement of juveniles from the South Santiam River into Foster Reservoir was unlike any pattern previously observed (Figure 12). The first subyearling from the 2014 BY was captured on June 9 (28 mm FL), similar to the June 14 capture of the first fry in 2013. However, very few *O. mykiss* of any age class were captured afterwards, until late October, when we captured more juveniles (N = 503) than in any previous one-week period. Our hypothesis for this late downstream migration is that winter steelhead adults spawned in tributaries as usual, but the extremely low flows from June – late October did not allow juvenile *O. mykiss* to exit the tributaries into the mainstem until the first freshets at the end of October.

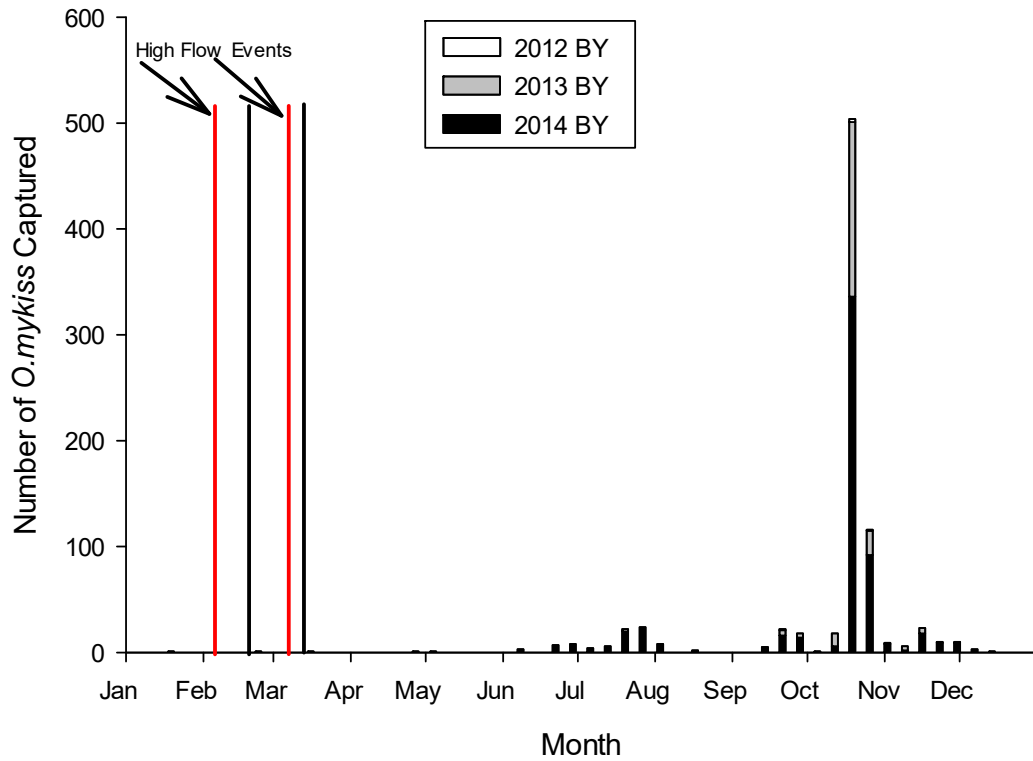


Figure 11. Weekly catch of juvenile *O. mykiss* captured in the South Santiam trap above Foster Reservoir, 2014. Red vertical lines indicate when trap was stopped due to anticipated high flow and black lines indicate when trap was re-started. BY = brood year.

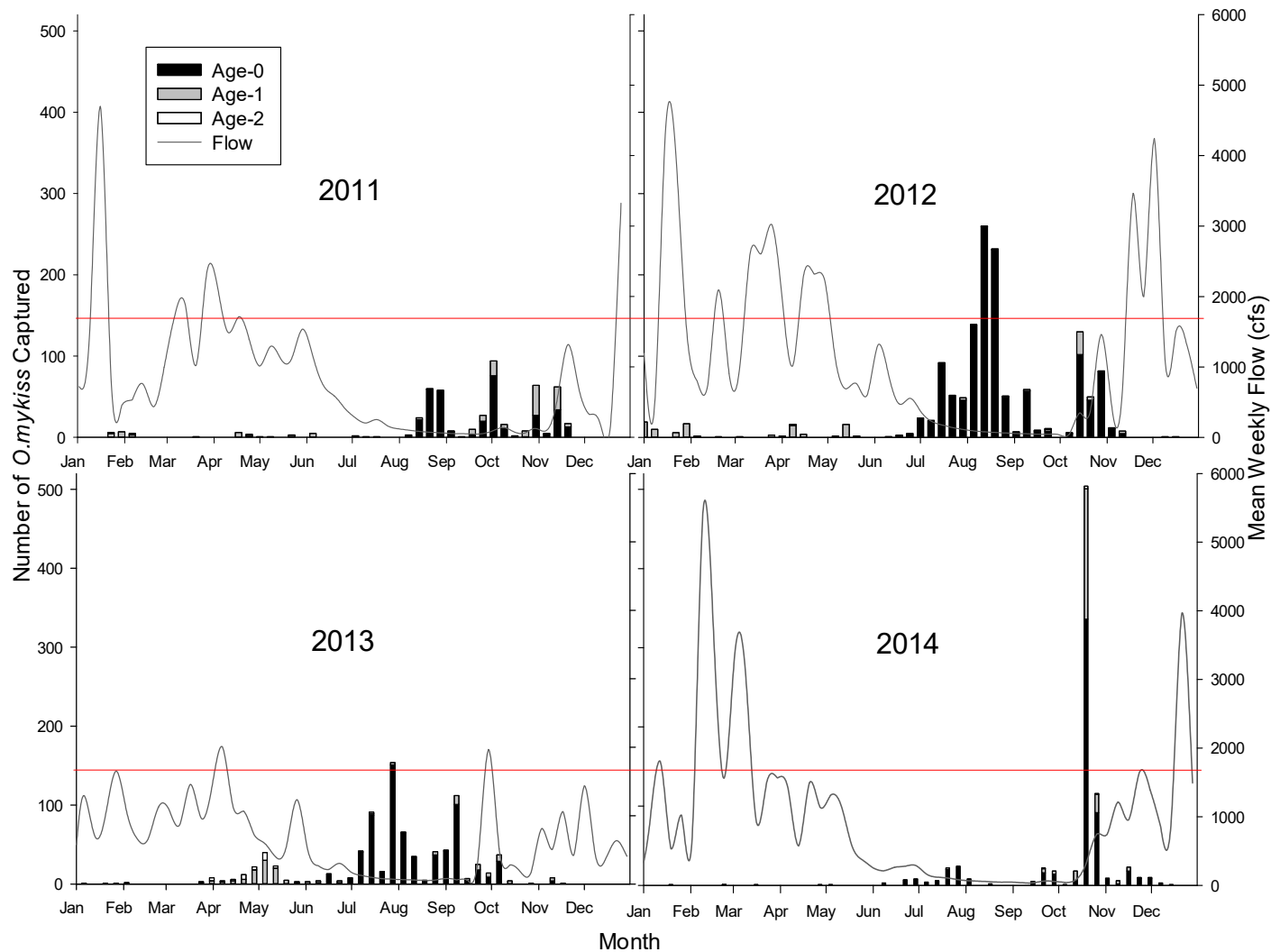


Figure 12. Number of *O. mykiss* captured in the South Santiam trap and mean weekly flow (ft^3/s) summarized by week for trapping seasons 2011-2014. Red horizontal line represents the flow level $1,680 \text{ ft}^3/\text{s}$, the maximum flow for trap operation.

In 2014, we snorkeled tributaries of the South Santiam River to capture and PIT-tag additional *O. mykiss* to collect information on migration timing, age of migration, and growth rates from subsequent recapture events and detections at downstream interrogation sites. We tagged 426 *O. mykiss* in Moose Cr, 101 in Canyon Cr., and zero in Soda Fork Cr. There was an abundance of both yearlings and subyearlings available for tagging in Moose and Canyon creeks in August - September. Because 2014 was the first tagging year in tributaries, we do not know whether this is typical for these tributaries during this period.

Below Foster Dam - The 2.4-m screw trap below Foster Dam operated from January 1 – December 22, 2014; 93% of the days that were available for fishing (338/364). This trap was removed from service March 8-19 for repairs, and again December 22 – 31 in anticipation of increased discharge. We also installed a 1.5-m trap to run in tandem with the larger trap from August 27 – December 22. The larger trap captured more fish of every species for every week that both traps fished, despite fewer revolutions per minute. Capture information for both traps are pooled in this report for simplicity. Dam discharge, reservoir elevation and corresponding catch for all species summarized by month are presented in Appendix D; Table D3 and Figure D4.

We captured 212 unmarked subyearling Chinook salmon (2013 BY) and five yearlings throughout the year. The first subyearling was captured January 31 and 44% of the total subyearlings captured below the dam were collected in February (Figure 13), with a mean size of 37 mm FL (range: 32-46 mm FL). Timing and size of fish below the dam were similar to fish entering the reservoir, and the number and timing were also very similar to 2013 (Romer et. al 2014). The peak Chinook salmon movement through Foster Dam typically includes the month of March. However, our trap was not operational March 8 – 19 so we likely missed a portion of the migration peak.

The migration timing and size of subyearling Chinook salmon collected below Foster Dam suggest that some subyearling Chinook salmon moved through Foster Reservoir into downstream rearing areas when the reservoir was at lower pool elevation (Appendix D; Figure D4). 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 (44 ft deep at full pool: penstock intake elevation 590 ft, full pool elevation 634 ft) and the affinity of subyearling juveniles for littoral zones and shallower water (Monzyk et al. 2014), our screw trap catch in the tailrace likely reflects overall trends in migration timing and relative abundance of subyearling salmonids, regardless of passage route. Hydroacoustic evaluations at Foster Dam in 2013-2014 suggested that most of the juvenile fish (regardless of species) passing the dam exit through the turbine units, a majority of them pass through turbine unit one, and peak passage timing observed by hydroacoustic monitoring corresponded fairly well to the direct-capture data from the tailrace screw trap (Hughes et al. 2014). Several 2014 brood year spring Chinook salmon (N=10) were captured below Foster Dam in late November and December, 2014 (Figure 14). As previously discussed this emergence timing is earlier than observed in the past. These fish were likely a result of spawning that occurred below the dam, as the first fish from the same brood year weren't captured upstream of Foster Reservoir until December 18.

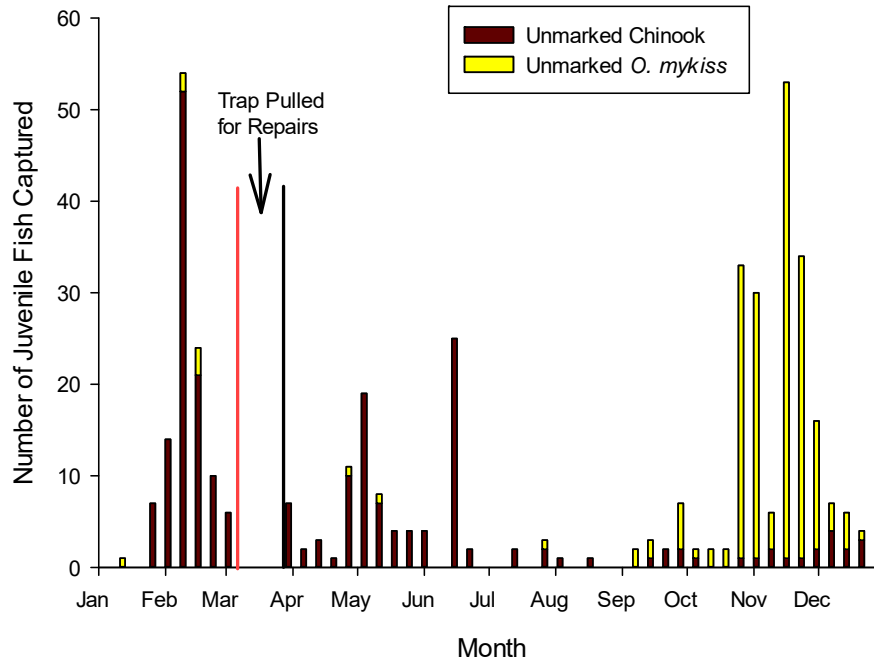


Figure 13. Weekly catch of unmarked Chinook salmon and *O. mykiss* captured below Foster Dam, 2014.

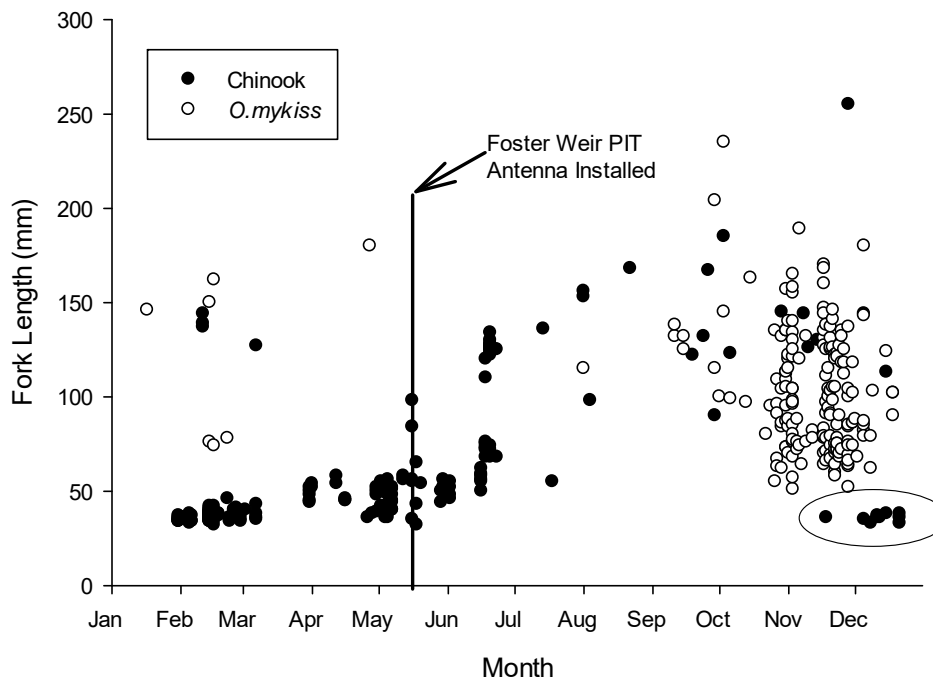


Figure 14. Fork lengths of unmarked juvenile spring Chinook salmon and *O. mykiss* captured in the rotary screw trap below Foster Dam, 2014. The black vertical line represents the installation of the PIT-tag antenna in Foster Dam fish weir. Oval indicates 2014 BY fry.

We also captured 195 *O. mykiss* below Foster Dam, compared to 141 in 2012, and only 38 in 2013. These ranged in size from 51-235 mm FL and were likely comprised of three age-classes (age 0-2). We were unable to reliably assign age from length-frequency analysis because of the large overlap in sizes (Figure 14). The overlap was probably due to differences in fish growth rates between the two rearing habitats (stream and reservoir) and the variable length of time individuals reared in the reservoir. We have documented that age-0 *O. mykiss* entering Foster Reservoir from the South Santiam River reach a maximum size ~100 – 110 mm FL by the end of December (Romer et. al 2014), so the *O. mykiss* < 100 mm FL captured below Foster from October-December were almost certainly age-0. Overall, *O. mykiss* captured below Foster Dam from September – December (n= 182) were larger than those captured in the South Santiam upstream of the dam (n= 746, Mann-Whitney rank sum test; $P = 0.004$).

Typically, the peak of the age-0 *O. mykiss* migration from the South Santiam River into Foster Reservoir occurs July-August (Figure 12) and the peak outmigration of this cohort from Foster Reservoir through Foster Dam occurs from October – December. In 2014, peak outmigration of age-0 *O. mykiss* through Foster dam occurred in November (67%, Figure 13) and appeared to be only slightly delayed in comparison to the peak migration of the subyearlings entering Foster Reservoir (Figure 11).

Delays in migration tended to be greater for subyearling *O. mykiss* than Chinook salmon, likely due to difference between the dates that these species typically enter Foster Reservoir. In contrast to Chinook salmon, most subyearling *O. mykiss* enter the reservoir July – September 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.

Foster Weir - The Foster Dam fish weir, deployed in spillway 4 to facilitate juvenile *O. mykiss* passage through the reservoir, was historically operated from April 15 to May 15. 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 migration timing 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 and age-1 *O. mykiss* through the reservoir without having to exit via the turbines.

In 2013 we PIT-tagged 791 *O. mykiss* (ages 0, 1, and 2) upstream of Foster Dam in anticipation of PIT-tag antenna installation early in the spring of 2014. On May 15, 2014 flat-plate antennas were positioned in the weir to detect PIT-tagged juvenile spring Chinook salmon and winter steelhead as they passed over the weir (Figure 15). However, from June 11 – 24 the antenna did not collect data, and we could not determine if the weir antenna was reliably detecting tags for the rest of the sampling season. On September 11, USACE stopped weir operations until October 15 before briefly re-deploying the antenna and finally removing it on

November 19. We continued tagging *O. mykiss* upstream of the dam throughout the trapping season for a total of 1,647 *O. mykiss* tagged in 2014 upstream of Foster Dam.

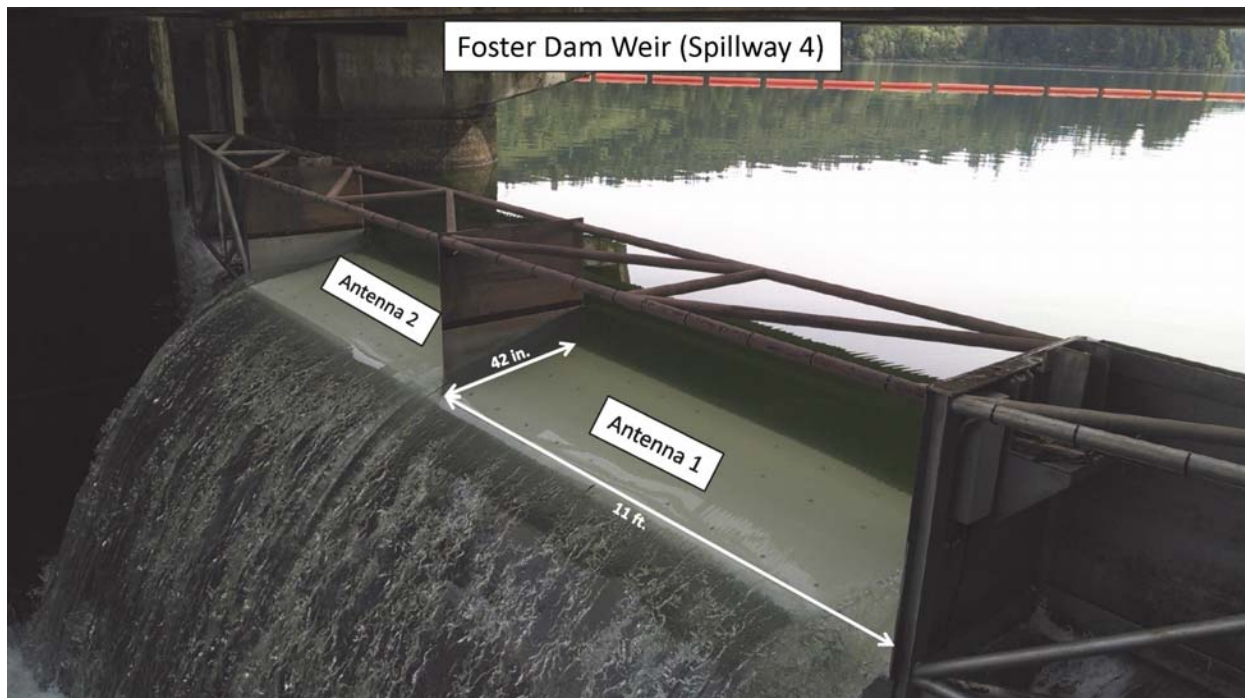


Figure 15. Foster Weir Antenna located in spillway 4 at Foster Dam.

Results from the limited weir antenna detections indicated that: 1) our screw trap catches a small proportion of the larger *O. mykiss* smolts leaving Foster Reservoir in the spring; and 2) 2-yr old *O. mykiss* smolt and emigrate downstream through the weir during the expected peak of outmigration. Of the 18 *O. mykiss* detections from our PIT-tagged fish, 17 were detected between May 15 – 31 and no *O. mykiss* were captured in the screw trap below the dam during this period. Fourteen of the detected fish were age 2, and four were age 1. Three of the age-2 fish were tagged as age 1 in 2013. We observed that fish detected by the weir antenna were not necessarily entrained for passage over the dam. That is, several fish were detected at the weir on multiple days, and we visually observed fish on top of the antenna that swam back upstream into Foster Reservoir.

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 sufficient data are 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 upstream of Foster Reservoir as subyearlings, and continue to rear farther downstream (possibly in the reservoir). These fish then migrate to the ocean, primarily as age-2 smolts. The proportion of each year-class that rears in Foster Reservoir is unknown.

In summary, results from hydroacoustic surveys, PIT-tag detections at the weir, and our trap catch suggest that our trap below Foster Dam is likely more efficient at catching smaller fish exiting the reservoir throughout the trapping season, but is less efficient at collecting larger fish,

particularly during the spring when smolts would be expected to migrate to the ocean. Spill operations from March – May likely entrain many smolts (and age-1 *O. mykiss*) which we were unable to sample. Spill also causes hydraulic conditions in the turbine tailrace that decrease rotations for the screw trap (mean rpm 2.6, range 0 – 10), possibly allowing larger fish to avoid our trap. In the fall - winter (September – December) the trap rotated faster and more consistently (mean rpm 3.8, range 0 - 9). We caught more fish (particularly *O. mykiss*) and fish of larger size during this period (Figure 14). This may be because more fish exited through the turbines, which had higher discharge in the fall than spillways (Figure D4). Indeed, a recent study conducted by PNNL found that a majority (4/7) of larger juvenile steelhead (122-188 mm FL) and Chinook salmon (63/82, 170-205 mm FL) that were released into Foster Reservoir in the fall of 2014 passed via the turbines (Hughes et al. 2015). Full understanding of *O. mykiss* behavior and life history strategies in the South Santiam River will require additional information from traps, radio-tagging studies, and/or PIT-tag detections at sites downstream of Foster Dam to confirm timing of dam passage and seaward migration.

Middle Fork Willamette River- We operated the Middle Fork Willamette (MFW) River trap upstream of Lookout Point Reservoir from February 27 through November 17, 2014. The trap fished for 242 d and captured 1,342 Chinook salmon subyearlings and 5 yearlings. The peak of the fry migration was March - May (Figure 16), and the median migration date was April 9 (Appendix B; Table B2).

Our estimated median migration date may be influenced by the date of our trap installation. 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 - 2014 we did not begin to operate the trap until mid-February, and captured juvenile Chinook salmon immediately following trap deployment in all years. There were no high-flow events in January 2012 - 2014 but we likely missed some of the early emergent juveniles migrating past the trap site. This may have slightly biased (late) the median migration dates from the 2012 - 2014 trapping seasons. The mean size of fry captured in February 2012 – 2014 was 35 – 36 mm FL.

The overall size range for subyearlings captured in the MFW trap upstream of Lookout Point Reservoir in 2014 was 27-119 mm FL (Figure 17). Fish exhibited greater variation in fork length than at any other trapping site, except for the South Santiam River (Figure 18). As documented in previous reports (Romer et al. 2012, 2013, 2014), several factors may have contributed 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 occurs. This is nearly twice the distance of any other trap, with 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 from Hills Creek Reservoir. These factors, along with higher temperatures, may explain why fish captured in the MFW trap were typically larger than their counterparts rearing in other sub-basins.

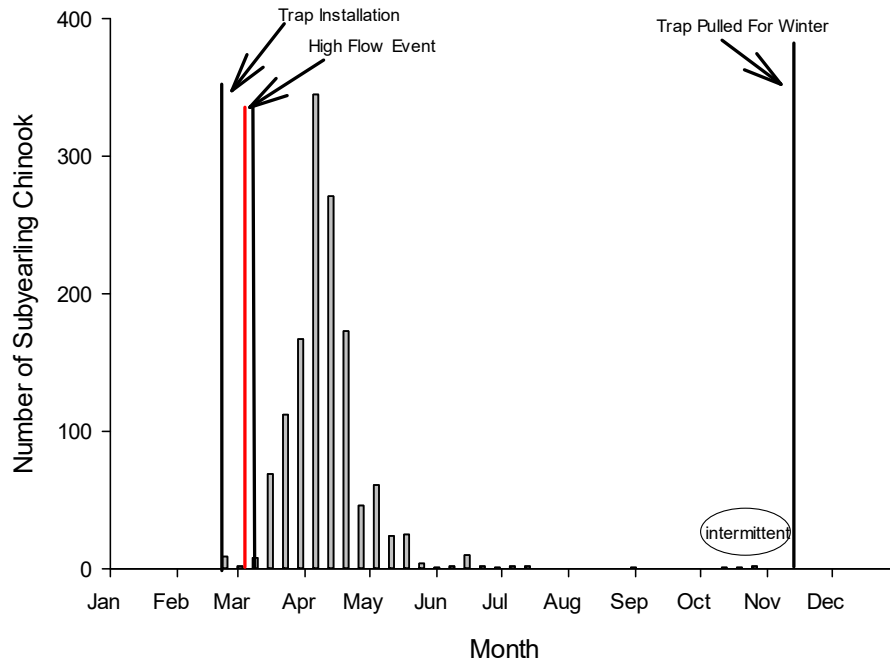


Figure 16. Weekly catch of subyearling spring Chinook salmon captured in the Middle Fork Willamette trap upstream of Lookout Point Reservoir, 2014. Intermittent refers to periods when trap operation was interrupted by poor flow conditions (too low or high) or high debris loads.

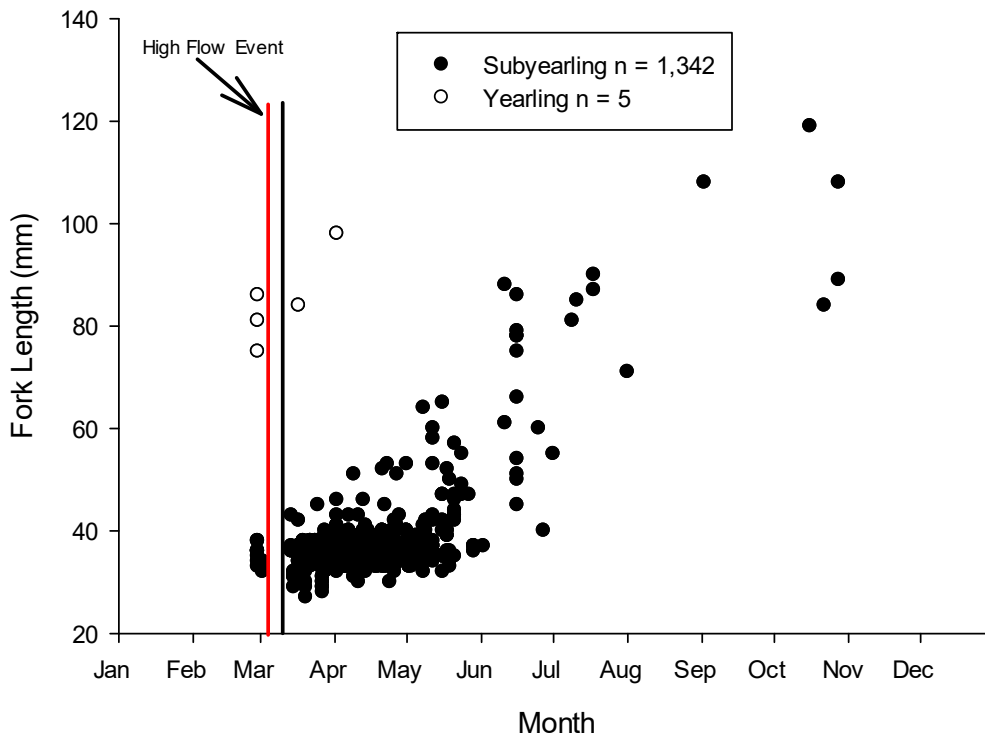


Figure 17. Fork length of subyearling and yearling Chinook salmon collected in the Middle Fork Willamette trap, 2014.

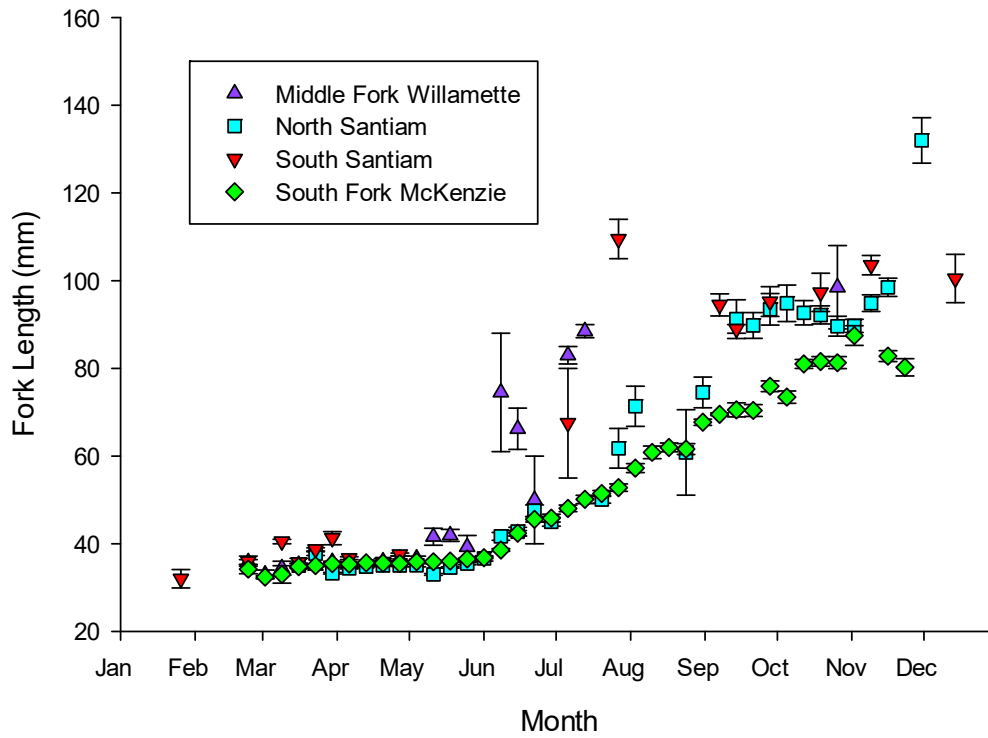


Figure 18. Fork lengths of subyearling spring Chinook salmon at each upstream screw trap location, 2014. Data were summarized by week and error bars represent the standard error.

Below Lookout Point Dam- Personnel from USACE operated a 2.4-m screw trap below Lookout Point Dam from January 1 to February 13, 2014. The trap captured three hatchery and four unmarked juvenile Chinook salmon (subyearling and yearling). Catch included one fry; collected on January 16, 2014. This trap was not operated for the rest of the year. Dam discharge, reservoir elevation and corresponding catch for all species, summarized by month, are provided in Appendix D; Table D4 and Figure D5.

As part of an ongoing paired-release study (Brandt et al. 2015 *in review*), dam discharge in 2014 (Appendix D; Figure D5) was controlled from April through June to mimic the discharge from 2011, 2012 and 2013. Research fish were released on June 5 near the head of Lookout Point Reservoir (~33,000 at Hampton boat ramp) and near the boat ramp in the forebay (~34,500). In 2014, no screw trap operated below Lookout Point Dam during this period to monitor fish movement through the dam. Until recently (2011), increased spill during summer months was atypical, relative to historical flow management regimes (Romer et al. 2012). Prior to 2011, 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 findings from data we have collected from most traps below dams in upper Willamette sub-basins.

South Fork McKenzie River- We operated the South Fork McKenzie River trap upstream of Cougar Reservoir from February 26 to November 26, 2014 and the trap fished for 251 d. The first fry were captured on February 27 (n=2), immediately after the trap was installed, suggesting that we may have missed some of the first emergent fry in the system. The peak fry capture occurred from April - May (Figure 19), with a median migration date of May 8 (Appendix B; Table B2). The distinct migration of subyearlings in early spring at this trap site was consistent with findings from previous work (Bureau of Commercial Fisheries 1960; Monzyk et al. 2011; Zymonas et al. 2012; Romer et al. 2012, 2013, 2014). Overall, we collected 11,402 Chinook salmon subyearlings and six yearlings. Growth of the subyearling cohort upstream of the reservoir was not evident until mid-June (Figure 20).

The size of subyearling Chinook salmon ranged from 29-107 mm FL, and the mean fork length from March through May was 36 mm (n = 2,875, SE 0.031), approximately the size at which most would be expected to enter the reservoir. Very few yearlings were captured upstream of the reservoir.

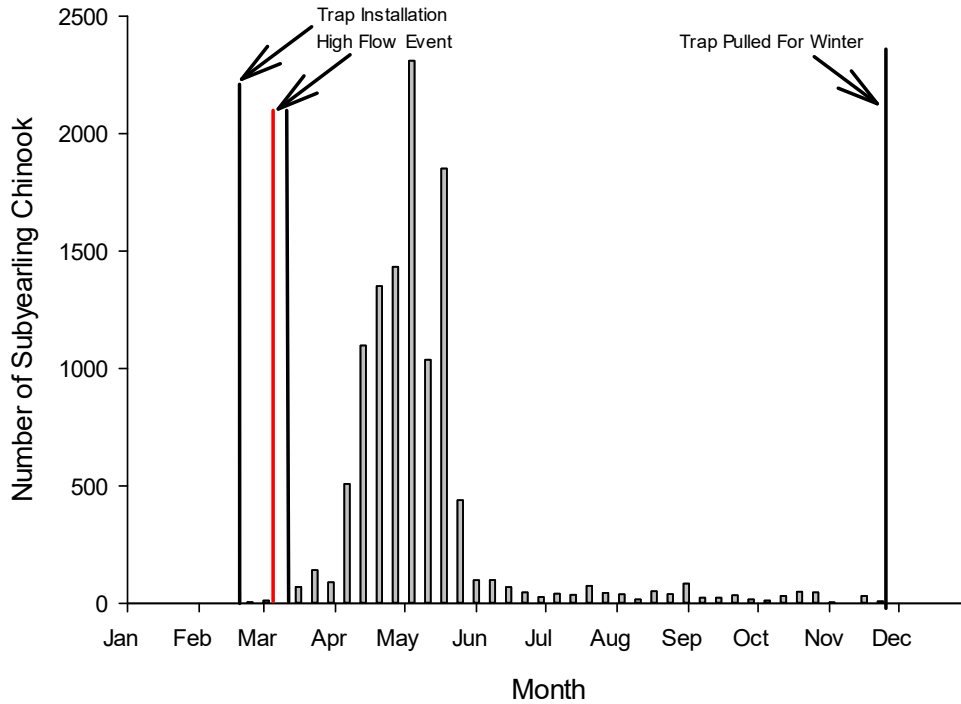


Figure 19. Weekly catch of subyearling spring Chinook salmon captured in the South Fork McKenzie River trap above Cougar Reservoir, 2014.

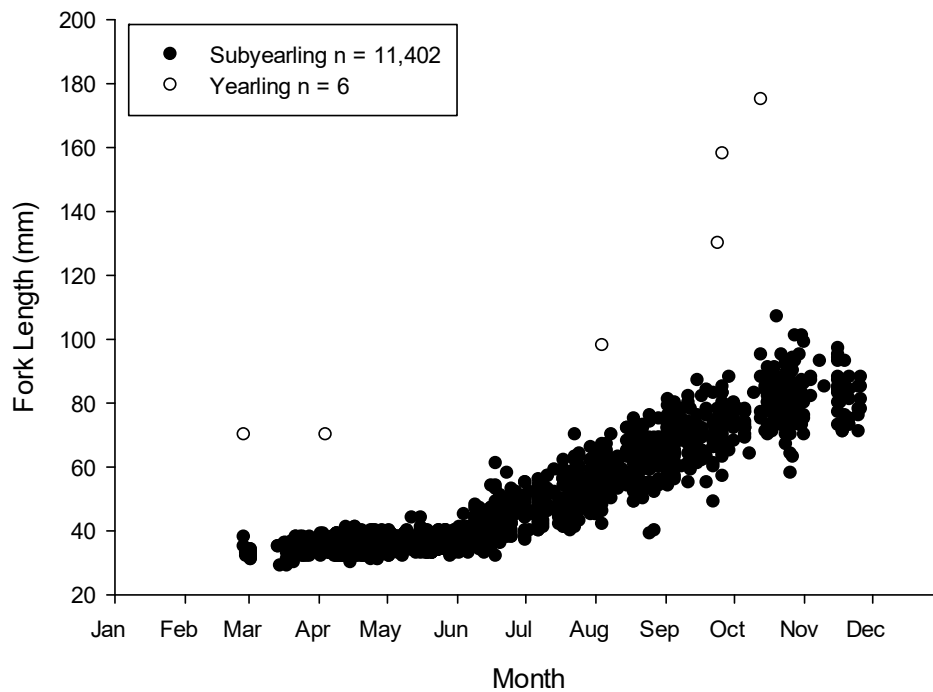


Figure 20. Fork length of subyearling and yearling Chinook salmon collected in the South Fork McKenzie River trap above Cougar Reservoir, 2014.

Below Cougar Dam – We operated three rotary screw traps below Cougar Dam in 2014. Traps were not operating January 17 – 27 and November 5 – 13 because of repairs. The total trap catch from all traps below the dam included 3,635 subyearling and 663 yearling unmarked Chinook salmon (Figure 22, Appendix D; Table D5).

Subyearling catch included 102 fry (< 60 mm FL) from February 18 – June 23 in both RO and tailrace traps (10 in the RO; 92 in tailrace). The first subyearlings were collected in the screw trap upstream of Cougar Reservoir on February 27, 2014 (n=2). This was the first day of operation for the upstream trap. This suggests there is possibly some production just below the dam in the substrate between the turbine tailrace and our trap below Cougar Dam. Alternatively, upstream trap deployment may not have been early enough to capture the first emerging fry and some fry may have traversed the reservoir and survived passage through both routes. A majority of the subyearlings (83%) passed the dam in November, coinciding with lower reservoir pool elevations and increased discharge, primarily from the regulating outlet (Figure 21, Appendix D; Figure D6). We captured juvenile Chinook salmon exiting both routes in similar numbers, with 55% exiting the RO, and 45% from the turbine tailrace in November. We also captured 44 hatchery Chinook salmon tagged by the USGS, which were similar in size and migration timing to naturally produced fish (Figure 22). Dam discharge, reservoir elevation and corresponding catch for all species summarized by month are provided in Appendix D; Table D5 and Figure D6.

In 2014, yearling dam passage timing was unlike that observed in 2013, but similar to previous years, with most fish passing in the early spring. In 2013 we observed relatively few yearlings passing the dam in the spring following the deep drawdown in December of 2012. The scarcity of yearlings did not appear to result from increased dam passage during the drawdown. Instead, the drawdown resulted in relatively little discharge from the dam from January-March 2013, as the reservoir refilled. In November 2013 we captured 31% of all yearlings collected below Cougar Dam for that year. In previous years we did not observe as many yearlings rearing for an additional summer in the reservoir. It is unclear whether the delayed outmigration of yearlings in November 2013 was related to the deep drawdown and subsequent low discharge conditions in the early spring of that year. However, it is plausible that less discharge may have caused fewer yearlings to outmigrate early in the year and explain our observations of yearlings throughout the remainder of the year. Again, in 2014, we observed a migration pattern whereby hundreds of yearlings passed the dam in the spring, and only 4% of the yearlings passed from October – December (Figure 22).

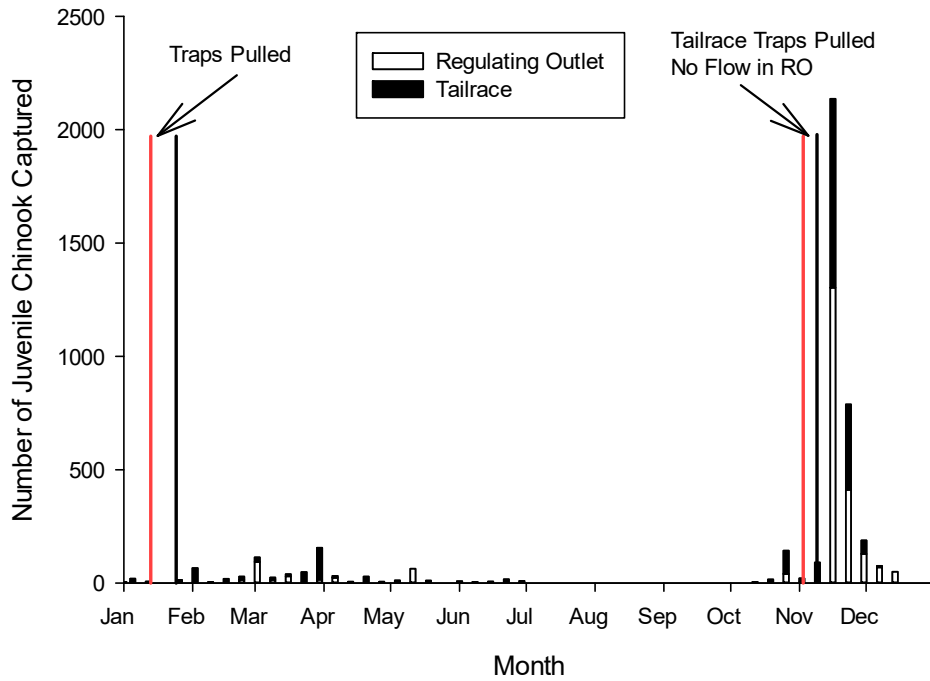


Figure 21. Weekly catch of unmarked juvenile spring Chinook salmon (subyearlings and yearlings) captured below Cougar Dam in rotary screw traps, 2014.

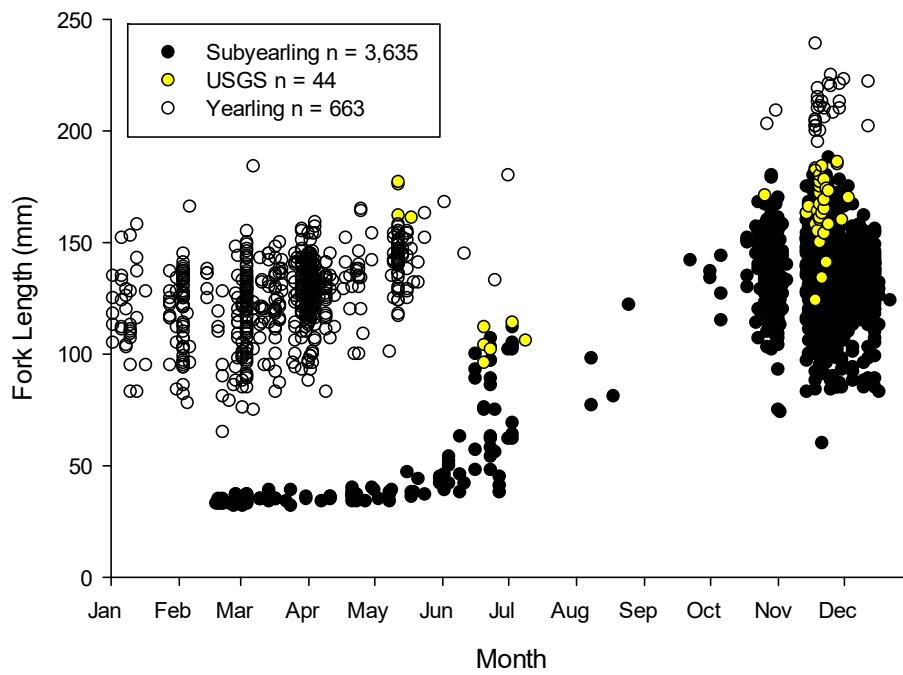


Figure 22. Relationship between fork length and capture date for natural-origin juvenile Chinook salmon sampled below Cougar Dam, 2014.

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 an adequately robust abundance estimate. Weekly trap efficiencies ranged from 1.3% to 13.2% with a weighted annual TE of 2.8% for 2014. We estimated that 415,741 (95% CI \pm 56,164) subyearlings (2013 BY) migrated past our screw trap and into Cougar Reservoir between January and December 2014. The vast majority (91%) of subyearlings moved into Cougar Reservoir as fry from March through May. Fry movement observed during the peak of the fry migration appeared to be somewhat correlated to stream flow in the South Fork McKenzie (USGS gauging station 14159200 near Rainbow; Figure 23). Once the fry had emerged, changes in weekly stream flow corresponded to changes in fry captured in the trap.

The subyearling abundance estimate for the 2013 BY may be biased low, because it does not include production that occurred below our trap site. Previously, an increase in the number of redds was observed downstream of the South Fork McKenzie screw trap (Table 3). Progeny from these redds were not included in our abundance estimates, so it is likely that abundance estimates for the 2011-12 brood years were also biased low. The number of redds below the trap were not counted prior to the high flow event on September 30, 2013 (1,390 ft³/s) near the peak of spring spawning season. This high flow may have washed away any evidence of Chinook salmon redds built below the trap prior to this date, and no redds were observed below the trap after the rain event. We do not know the survival rate of the eggs to emergence for redds near the head of the reservoir, but the contributions of 12% and 13% of the overall redds counted for the 2011 and 2012 BY (respectively) is presumably important.

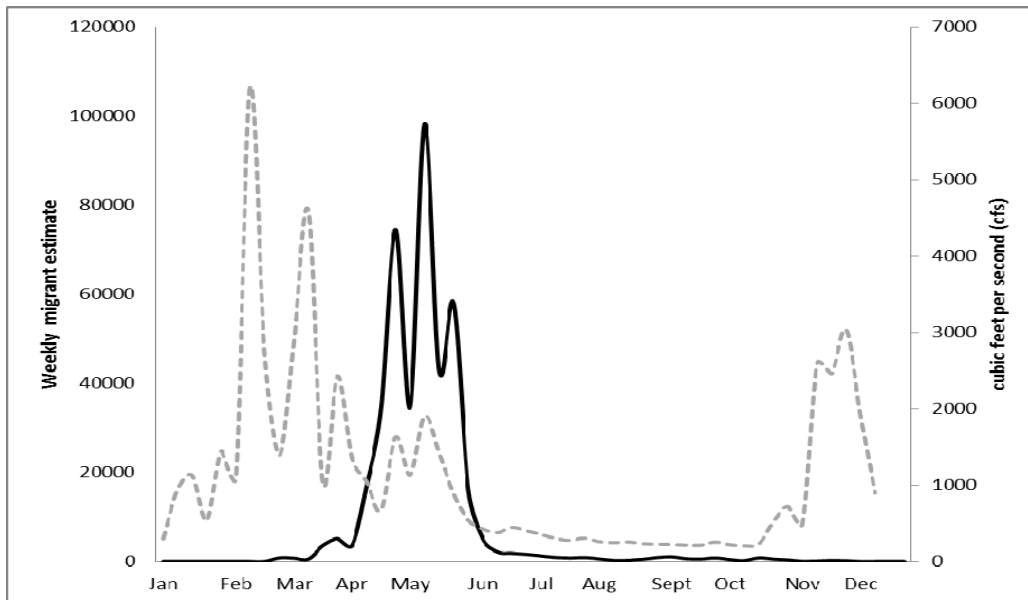


Figure 23. The estimated number of subyearling spring Chinook salmon migrating past the South Fork McKenzie trap and maximum flow level in 2014, summarized by week. Estimated number of subyearlings is represented by the solid black line and corresponding flow is represented by the dotted grey line.

Table 3. 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. (2014).

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

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

Below Cougar Dam –Trap efficiencies below the dam did not meet our criteria for providing an accurate estimate of the number of 2013 BY subyearlings that survived to pass below Cougar Dam. In fact, there were only 12 weeks that we captured more than ten juvenile Chinook salmon below the dam, and in only one week did we recapture five or more fish that had been marked to estimate trap efficiencies.

Recommended Future Directions

Our data demonstrates 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. The data also provides evidence that suggest subyearling Chinook salmon and *O. mykiss* are the prominent year class emigrating from streams into WVP reservoirs. Reservoir-rearing fish grow larger and more quickly than those rearing in rivers upstream of our screw traps. Growth advantages of reservoir fish could result in increased survival to adulthood (Claiborne et al. 2011; ISRP 2011). However, potential benefits from reservoir rearing must be weighed against potential risks to population productivity that may be posed by increased residualism rates, younger age at maturity and higher downstream passage mortality experienced by larger smolts (Taylor 2000; Normandeau 2010; Keefer et al. 2012; Zymonas et al. 2012). Juvenile salmonids that rear in WVP reservoirs are also exposed to intense predation and copepod infections (Monzyk et al. 2012, 2013, 2014, 2015 *in press*), though the full effects from these risks have not yet been assessed. Management strategies that aim to provide safe passage around or through reservoirs and dams for earlier life-stages, including at-dam passage structures and interim dam operations may help to maintain life-history diversity, especially 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 (Romer et al. 2014, Figure 4). We suggest facilitating sub-basin specific outmigration through operations such as delayed refill in the spring whenever possible. We hypothesize that safe and early passage of more fish of a smaller size would likely also help mitigate the potential risks of copepod infection and predation. We present peak migration periods for juvenile

salmonids entering each of the reservoirs from 2010-2014 in Appendix B, Table B3 to assist with the development of management that would allow such passage.

We will continue to operate rotary screw traps at the same locations in 2015, with a few exceptions and additions. We are relocating the current trap from the site at the Middle Fork Willamette River upstream of Lookout Point Reservoir to the North Fork Middle Fork Willamette River (NFMF), attempting to estimate the number of migrants produced in that sub-basin. This differs from the current trapping site, where trap efficiency was < 1% most of the year and where we were unable to determine the origin of fish captured in the trap from the NFMF or emigrating from above or below Hills Creek Reservoir and. We will install a trap in the Middle Fork Willamette River upstream of Hills Creek Reservoir to collect information on migration timing and size of Chinook salmon. We note that 79 redds were counted in the Breitenbush River in 2014, so the screw trapping site at that location will be re-activated. Our 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 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.

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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 2014.

Location	Subyearling	Yearling	Total
South Fork McKenzie ^a	796	16	812
Cougar Reservoir	295	0	84
Cougar Tailrace	219	1	220
Breitenbush River ^b	0	0	0
North Santiam River	155	4	159
Detroit Reservoir	0	0	0
Big Cliff Tailrace	9	0	9
Lookout Point Reservoir	0	1	1
South Santiam River ^c	40	0	40
Foster Reservoir	54	0	54
Foster Tailrace	45	0	45
Total	1,613	22	1,635

^a 341 of the subyearlings and 10 yearlings were tagged while seining

^b No sampling was conducted in the Breitenbush in 2014

^c Eight subyearlings were tagged while seining and one using hook and line

Table A2. Number of juvenile Chinook salmon PIT-tagged in screw traps and reservoirs by the Willamette Reservoir Research Project, 2010-2014.

Location	2010	2011	2012	2013	2014	Total
South Fork McKenzie R.	83	615	897	1,287	812	3,694
Cougar Reservoir	440	547	537	84	295	1,903
Cougar Tailrace	--	1,072	308	14	220	1,614
Breitenbush R.	8	111	--	--	--	119
North Santiam R.	231	184	25	76	159	675
Detroit Reservoir	--	58	--	--	--	58
Detroit Tailrace	--	66	7	3	--	76
Big Cliff Tailrace	--	--	--	--	9	9
Middle Fork Willamette	76	36	36	148	--	296
NFMF Willamette R.	109	78	177	--	--	364
Lookout Point Reservoir	83	72	1	5	1	162
South Santiam R.	67	1	12	45	40	165
Foster Reservoir	--	--	--	60	54	114
Foster Tailrace	--	2	4	25	45	76
Total	1,097	2,842	2,004	1,747	1,635	9,325

Table A3. Juvenile Chinook salmon PIT-tagged above and below Willamette Valley Project Dams 2010-2014 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
North Santiam River	Willamette Falls	3	2	0	0	0
	Columbia River Trawl	1	0	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	0
South Santiam River	Willamette Falls	4	0	0	1	1
Foster Reservoir	Willamette Falls	--	--	--	1	0
Foster Tailrace	Willamette Falls	--	--	0	4	5
SF McKenzie River	Cougar Reservoir	0	4	0	0	0
	Cougar Tailrace	0	10	14	19	4
	Leaburg	0	15	23	53	17
	Walterville	--	0	19	18	6
	Willamette R3 (175-301)	0	0	1	0	0
	Willamette Falls	0	2	10	4	0
	Columbia River Trawl	0	1	0	0	0
Cougar Reservoir	Will. Falls Adult Fish Ladder	1	0	0	0	0
	Cougar Reservoir	2	6	9	0	2
	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
Cougar Tailrace	Will. Falls Adult Fish Ladder	0	1	0	0	0
	Leaburg	0	204	51	5	77
	Walterville	0	23	3	4	12
	Willamette Falls	0	12	4	1	3
	Columbia River Trawl	0	1	0	0	0
	East Sand Island	0	0	1	0	0
	Will. Falls Adult Fish Ladder	0	1	1	0	0
NFMF Willamette River	Cougar Trap & Haul	0	1	0	0	0
	Willamette Falls	--	1	2	--	--
	Columbia River Trawl	--	0	1	--	--
Middle Fork Willamette River	Will. Falls Adult Fish Ladder	--	1	0	--	--
	Lookout Point Reservoir	0	0	2	2	--
	Willamette R3 (175-301)	0	0	0	2	--
	Willamette Falls	0	0	0	3	--
Lookout Point Reservoir	East Sand Island	1	0	0	0	--
	Willamette Falls	1	0	0	0	--

Table A4. Number of juvenile *O. mykiss* PIT-tagged by the Willamette Reservoir Research Project in the South Santiam sub-basin, 2011-2014 (Romer et al. 2011, 2012, 2013).

Location	2011	2012	2013	2014	Total
South Santiam	205	321	361	1,149	2,036
Foster Reservoir	--	--	430	498	928
Foster Tailrace	--	49	9	155	213
Total	205	370	800	1,802	3,177

Table A5. Juvenile *O. mykiss* PIT-tagged above and below Foster Dam on the South Santiam River 2011-2014 and subsequently detected at downstream recapture or interrogation sites. -- denotes years when no *O. mykiss* were tagged at this location. Year refers to the year the fish were tagged.

Tagging Location	Recap/Interrogation Location	2011	2012	2013	2014
South Santiam River	Foster Reservoir	--	--	3	10
	Foster Weir	--	--	2	1
	Foster Tailrace	--	0	0	4
	Willamette Falls	0	1	1	0
	Columbia River	2	0	0	0
	East Sand Island	1	0	0	0
Foster Reservoir	Foster Reservoir	--	--	6	17
	Foster Weir	--	--	1	14
	Foster Tailrace	--	--	0	2
	Willamette Falls	--	--	14	0
	Columbia River	--	--	2	0
	East Sand Island	--	--	3	0
Foster Tailrace	Willamette Falls	--	0	0	0
	Columbia River	--	0	0	0
	East Sand Island	--	0	1	0

Appendix B. Basin-wide information.

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

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

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

Table B2. Yearly median migration date for subyearling Chinook salmon migrating past Willamette Reservoir Research Project traps. ^a Trap was not running for a 26-day window during what has been the peak of outmigration in previous years.

Median Migration Date					
Location	2010	2011	2012	2013	2014
North Santiam	-	May 6	May 14	May 14	May 8
Breitenbush	-	Mar 8	-	-	-
South Santiam	-	-	Mar 7	Feb 28	- ^a
South Fork McKenzie	May 1	May 16	May 16	Apr 26	May 8
Middle Fk. Willamette	-	Mar 28	Apr 13	Apr 4	Apr 9

Table B3. Peak months of juvenile steelhead and subyearling spring Chinook salmon migration into reservoirs in all rivers with rotary screw traps (2010-2014).

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; 2009-2013). Data are summarized on a 23-month scale corresponding to the typical reservoir exit timing for the entire cohort. Asterisks denote the last available month of data collection.

Life Stage	Month	2009 BY	2010 BY	2011 BY	2012 BY	2013 BY
Fry (< 60 mm)	Feb	0	0	0	0	24
Fry (< 60 mm)	Mar	0	13	6	0	26
Fry (< 60 mm)	Apr	9	1	6	118	18
Fry (< 60 mm)	May	1	1	23	60	15
Fry/Subyearling	Jun	127	9	25	218	34
Fry/Subyearling	Jul	0	17	12	20	9
Fry/Subyearling	Aug	80	38	380	31	4
Subyearling	Sep	26	19	60	60	1
Subyearling	Oct	60	90	250	940	137
Subyearling	Nov	905	942	1,068	2,605	3,113
Subyearling	Dec	2,155	125	1,174	272	242*
Yearling	Jan	373	288	6	46	
Yearling	Feb	72	4	2	95	
Yearling	Mar	62	12	2	217	
Yearling	Apr	242	82	35	191	
Yearling	May	153	20	96	73	
Yearling	Jun	48	5	26	3	
Yearling	Jul	10	0	0	1	
Yearling	Aug	0	0	0	0	
Yearling	Sep	1	0	0	0	
Yearling	Oct	0	2	15	2	
Yearling	Nov	17	13	62	24	
Yearling	Dec	2	6	0	3	
	Total	4,343	1,687	3,248	4,979	3,623

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, 2014. Mysis shrimp counts are estimates. Mk = fin-marked; Unmk = unmarked.

Month	Chinook salmon		Rainbow Trout		Kokanee	Mountain Whitefish	Dace	Pumpkinseed & Bluegill	Mysis Shrimp
	Mk	Unmk	Mk	Unmk					
JAN	0	1	0	4	17	0	0	6	5,150
FEB	23	26	0	0	1,877	0	0	7	550
MAR	0	0	0	0	270	0	0	0	0
APR	-	-	-	-	-	-	-	-	-
MAY	-	-	-	-	-	-	-	-	-
JUN	-	-	-	-	-	-	-	-	-
JUL	-	-	-	-	-	-	-	-	-
AUG	-	-	-	-	-	-	-	-	-
SEPT	-	-	-	-	-	-	-	-	-
OCT	-	-	-	-	-	-	-	-	-
NOV	-	-	-	-	-	-	-	-	-
DEC	-	-	-	-	-	-	-	-	-
TOTAL	23	27	0	4	2,164	0	0	13	5,650

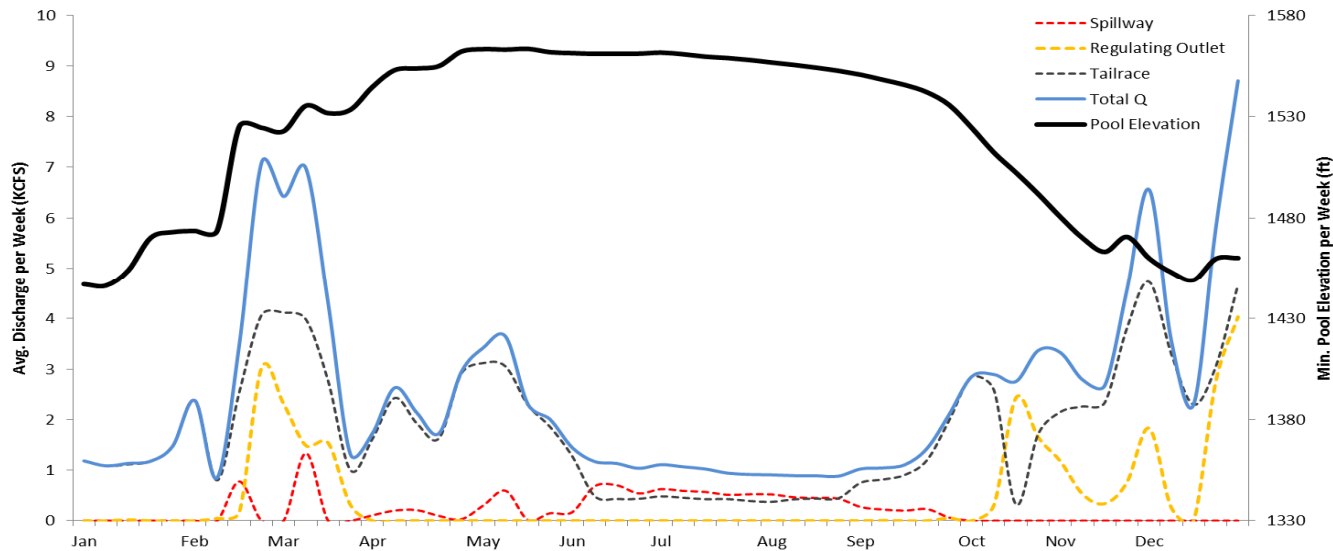


Figure D1. Detroit Dam discharge (Q) and reservoir pool elevation, 2014. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.

Table D2. Number of each species captured in the screw traps below Big Cliff Dam by species and month, 2014. Mysis shrimp counts are estimates. Mk = fin-marked; Unmk = unmarked.

Month	Chinook salmon		Rainbow Trout		Kokanee	Mountain Whitefish	Sculpin	Pumpkinseed & Bluegill	Mysis Shrimp
	Mk	Unmk	Mk	Unmk					
JAN	-	-	-	-	-	-	-	-	-
FEB	-	-	-	-	-	-	-	-	-
MAR	-	-	-	-	-	-	-	-	-
APR	11	8	0	1	11	0	15	7	0
MAY	0	2	4	4	2	0	3	38	0
JUN	1	6	0	1	0	0	0	43	0
JUL	0	7	0	5	1	0	0	21	4,200
AUG	5	6	0	3	0	0	2	1	0
SEPT	9	1	0	6	3	0	0	30	0
OCT	10	6	0	4	8	0	0	211	0
NOV	53	54	0	0	30	0	0	1,017	0
DEC	30	35	0	3	17	1	1	10	0
TOTAL	119	125	4	27	72	1	21	1,378	4,200

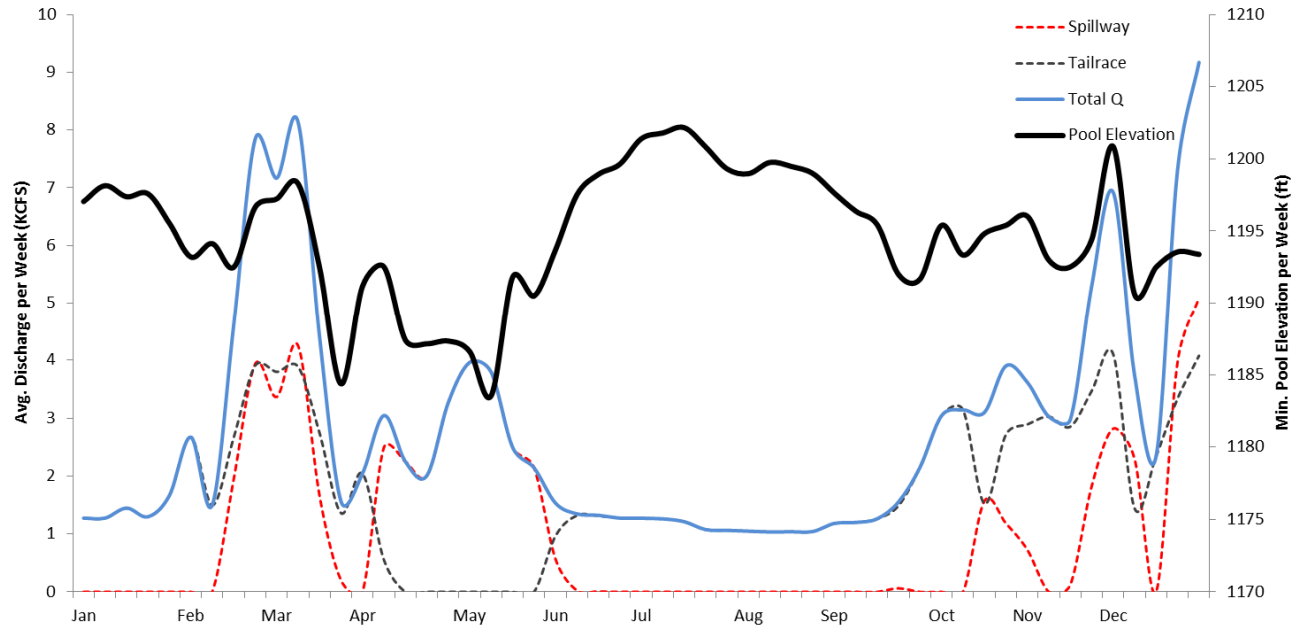


Figure D2. Big Cliff Dam discharge (Q) and reservoir pool elevation, 2014. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.

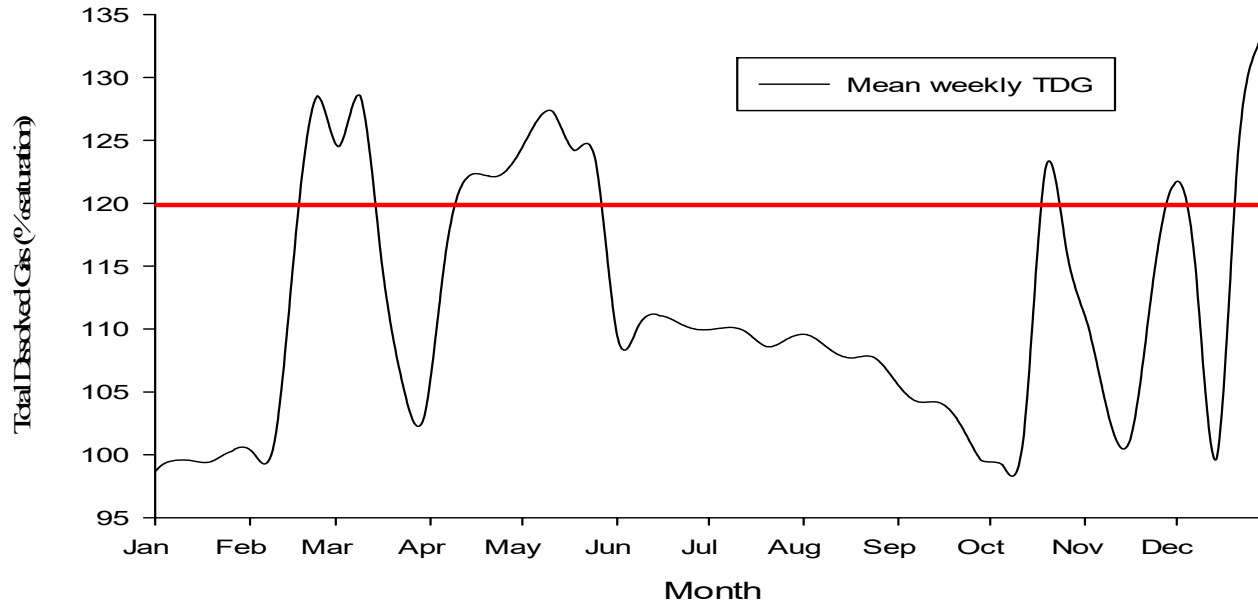


Figure D3. Total dissolved gas (TDG; % saturation) downstream of Big Cliff Dam on the North Santiam River measured at Niagara (USGS gauging station 14181500), 2014.

Table D3. Number of each species captured in the screw trap below Foster Dam summarized by species and month, 2014. Mk = fin-marked; Unmk = unmarked.

Month	Chinook salmon		<i>O. mykiss</i>		Kokanee	Cutthroat	Yellow Perch	Bluegill	Crappie	Largescale Sucker	Dace	Northern Pikeminnow	Brook Lamprey	Redside Shiner
	Mk	Unmk	Mk	Unmk										
JAN	0	7	0	1	31	0	148	0	0	0	0	0	1	0
FEB	2	97	4	5	24	0	484	4	0	0	0	1	7	0
MAR	22	11	1	0	3	0	146	1	0	0	1	0	21	0
APR	1	13	5	1	5	0	97	2	0	2	5	0	10	0
MAY	0	39	5	1	2	0	45	8	0	1	2	0	6	0
JUN	0	31	2	0	0	0	13	0	0	0	0	0	3	0
JUL	1	2	4	0	0	0	0	0	0	0	0	0	0	0
AUG	2	4	11	1	0	0	0	0	0	0	0	0	0	0
SEPT	1	4	5	6	1	0	2	1	0	0	1	0	0	0
OCT	28	3	7	33	13	4	113	49	0	60	14	117	0	1
NOV	277	4	10	131	911	13	721	73	0	15	4	476	7	5
DEC	4	11	3	15	375	0	142	6	0	5	2	28	3	1
TOTAL	338	226	57	194	1,365	17	1,911	144	0	83	29	622	58	7

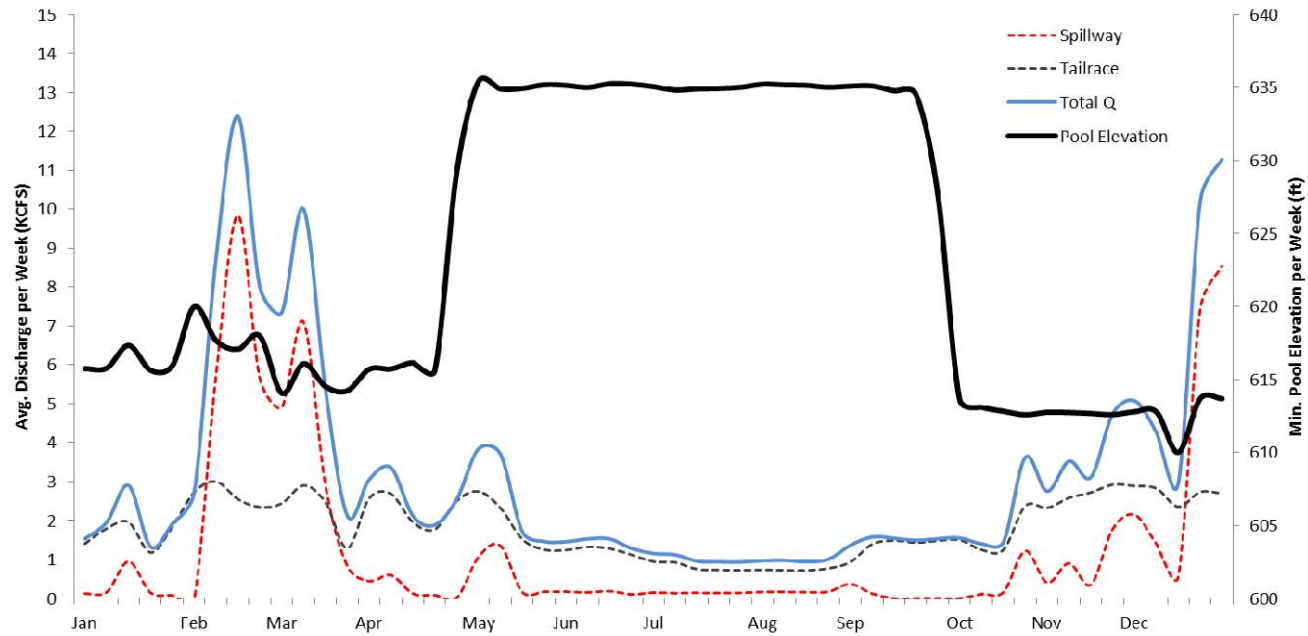


Figure D4. Foster Dam discharge (Q) and reservoir pool elevation, 2014. Discharge is reported as the weekly average and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.

Table D4. Number of each species captured in the screw trap below Lookout Point Dam summarized by species and month, 2014. Mk = fin-marked; Unmk = unmarked.

Month	Chinook salmon		Northern Pikeminnow	Bass	Crappie	Pumpkinseed & Bluegill	Sculpin	Largescale Sucker
	Mk	Unmk						
JAN	3	4	0	0	1	0	7	0
FEB	0	0	0	0	1	0	0	0
MAR	-	-	-	-	-	-	-	-
APR	-	-	-	-	-	-	-	-
MAY	-	-	-	-	-	-	-	-
JUN	-	-	-	-	-	-	-	-
JUL	-	-	-	-	-	-	-	-
AUG	-	-	-	-	-	-	-	-
SEPT	-	-	-	-	-	-	-	-
OCT	-	-	-	-	-	-	-	-
NOV	-	-	-	-	-	-	-	-
DEC	-	-	-	-	-	-	-	-
TOTAL	3	4	0	0	2	0	7	0

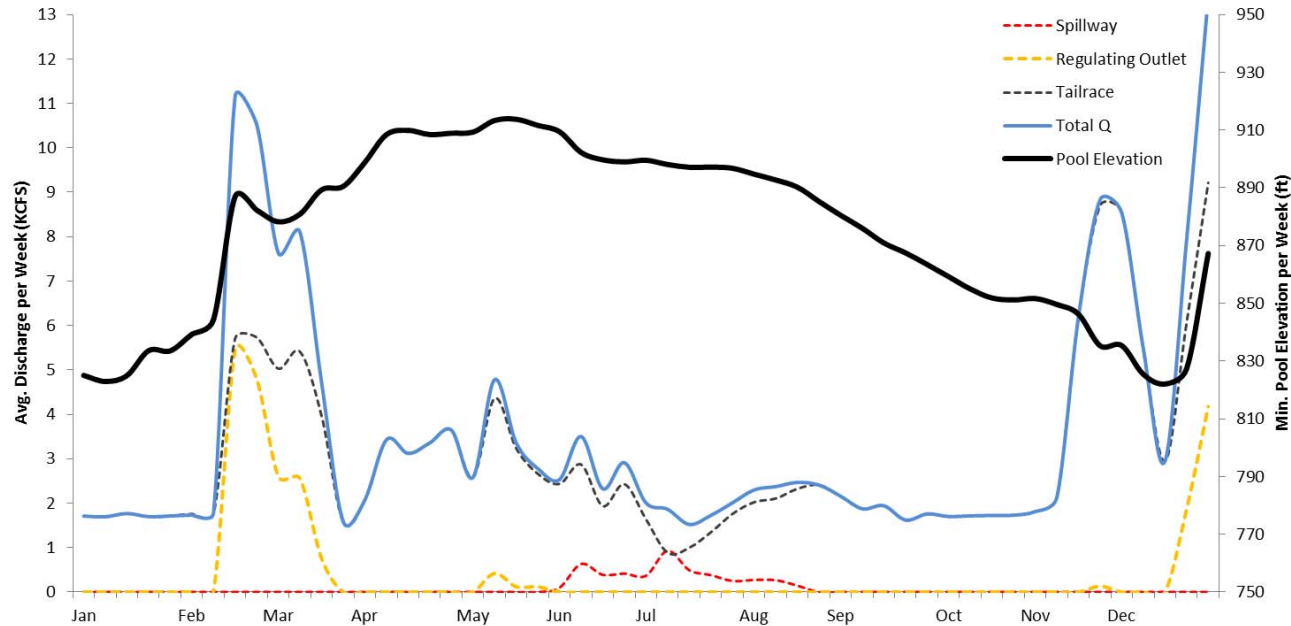


Figure D5. Lookout Point Dam discharge (Q) and reservoir pool elevation, 2014. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week.

Table D5. Number of each species captured in the screw trap below Cougar Dam summarized by species and month, 2014. All Chinook salmon and rainbow trout were unmarked.

Month	Chinook salmon	Rainbow Trout	Cutthroat	Trout Fry	Bull Trout	Mountain Whitefish	Dace	Brook Lamprey	Sculpin	Bass	Bluegill
JAN	46	0	0	0	0	9	0	0	1	0	0
FEB	119	0	0	0	0	0	1	0	0	0	0
MAR	246	2	1	0	0	0	3	0	1	0	0
APR	209	5	0	0	0	0	2	0	3	0	0
MAY	93	7	0	0	0	0	15	0	1	0	0
JUN	37	8	1	32	0	0	10	0	0	0	0
JUL	10	3	0	3	0	0	7	0	14	0	0
AUG	4	3	0	0	0	0	2	0	18	3	0
SEPT	1	2	0	0	0	1	0	0	2	0	0
OCT	139	5	0	0	0	1	0	0	2	0	0
NOV	3,148	1	0	0	0	1	0	0	0	0	1
DEC	246	1	0	0	1	0	0	0	0	0	0
TOTAL	4,298	37	2	35	1	3	40	0	42	3	1

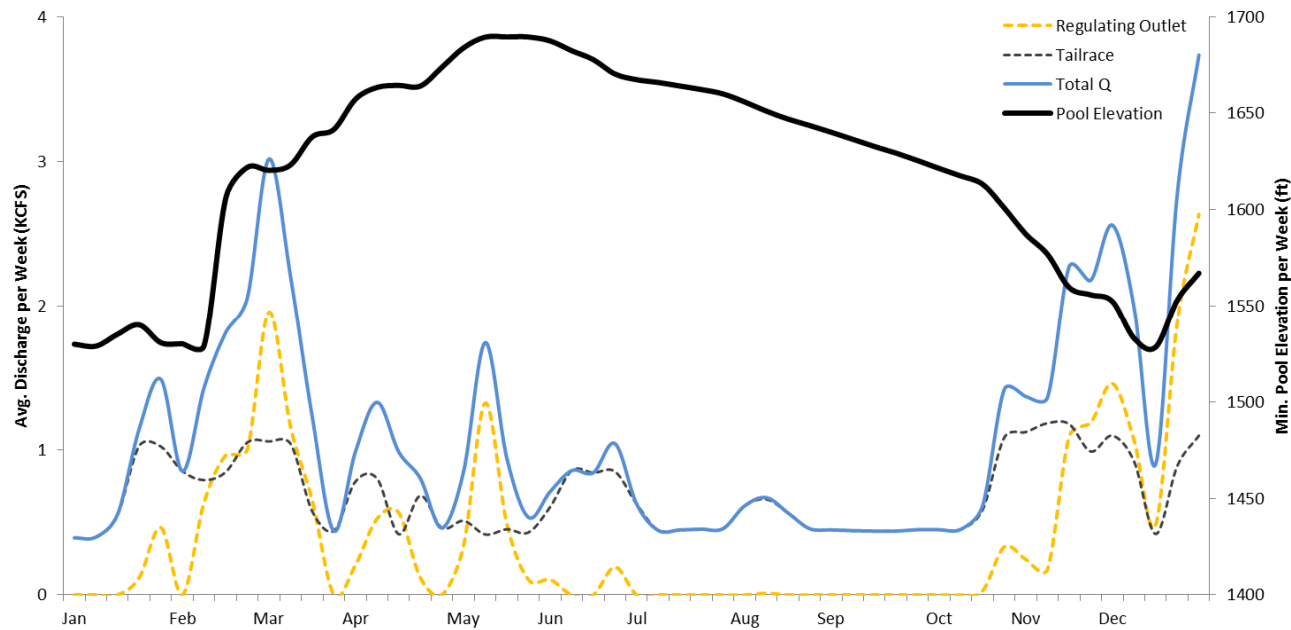


Figure D6. Cougar Dam discharge (Q) and reservoir pool elevation, 2014. Discharge is reported as the weekly average, and pool elevation is reported as the minimum elevation for each week. Tailrace = turbine outflow.