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MIGRATION, SURVIVAL, GROWTH, AND FATE OF HATCHERY JUVENILE CHINOOK SALMON RELEASED ABOVE AND BELOW DAMS IN THE WILLAMETTE RIVER BASIN

Prepared for
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Summary

Upper Willamette River (UWR) spring Chinook salmon *Oncorhynchus tshawytscha* are listed as a threatened species under the U.S. Endangered Species Act (NMFS 1999; NMFS 2005). In its 2008 Biological Opinion (BiOp) for the Willamette River Basin Flood Control Project ("Project"), the National Marine Fisheries Service identified lack of fish passage at Project dams as a major limiting factor to the viability of UWR Chinook salmon (NMFS 2008). The BiOp directed actions to identify, address and reduce impacts from existing dam passage conditions for adult and juvenile Chinook salmon, including continued trap, transport and release of adult salmon into above-dam habitats (Reasonable and Prudent Alternative [RPA] 4.1), and studies to investigate the feasibility of improving downstream fish passage at Project dams (RPA 4.12) (NMFS 2008). Together, these actions are intended to re-establish viable populations of naturally-spawning UWR Chinook salmon in their historical habitats above Willamette Project dams.

In 2011, we began releasing PIT-tagged juvenile Chinook salmon at sites above and below Project dams in the Middle Fork Willamette (MFW) River and using detections of these fish at Willamette Falls and other locations to estimate the effects that residence and passage through reservoirs and dams have on the growth, movement patterns and survivorship to adulthood of this species. In 2012, we initiated a parallel study in the North Santiam (NS) River. Results for fish released in 2011-2013 were described by Brandt et al. (2016) and Johnson et al. (2016) described results for 2014 releases. Here we report results from subyearling Chinook salmon released into the North Santiam River in 2015, and describe preliminary findings for adult returns from previous years' releases in both basins.

On 6 August 2015, we released 98,835 PIT-tagged hatchery Chinook salmon into the North Santiam River. These fish had been divided into three approximately equal groups and were scheduled to be released at the head of Detroit Reservoir (DET HOR), Detroit forebay (DET FB), and Big Cliff Dam tailrace (BC TR) sites. Due to severe summer drought conditions, water temperatures in the Detroit forebay were unacceptably high (and the reservoir elevation too low) at the scheduled time of release. After consulting with the USACE we instead released those fish intended for the Detroit forebay at the head of reservoir. Accordingly, two groups of unequal size were released from two sites in the North Santiam in 2015, DET HOR (N = 65,981) and BC TR (N = 32,855).

Based on raw (unadjusted) detections, the proportions of fish subsequently detected at Willamette Falls did not differ significantly between release groups (DET HOR = 0.013 and BC TR = 0.012; z-test, $P = 0.371$). To better estimate the total number of fish from each group that outmigrated past Willamette Falls, we applied the expansion factor developed by Schroeder et al. (2016) to our detection data, which accounts for the effects of flow and entrainment on tag detection efficiency to provide an estimate for the number of fish passing the falls under variable conditions. We used these expanded estimates to compare outmigration success between groups released into the NS in 2015, and found that a significantly greater proportion of fish released at BC TR (0.227) successfully outmigrated past Willamette Falls, relative to those released at DET HOR (0.079) (z-test; $P < 0.001$). The number of fish detected at Stayton Canal and upper Bennett Dam (NSS and NSB; total N = 7,031) was higher than observed at Willamette Falls

(SUJ; N = 1,280), and the ratio of BC TR to DET HOR detections observed at NSS-NSB (2.4:1) was nearly reciprocal when compared to SUJ (1:2.1) (all numbers and rates were based on unadjusted counts). Median travel rates to NSS-NSB were significantly faster for the BC TR group (2.4 rkm/d), relative to the above-dam release group DET HOR (0.6 rkm/d). Conversely, the median travel rate to Willamette Falls for the DET HOR group (2.4 rkm/d) was significantly greater ($P < 0.001$) than the median travel rate for the BC TR fish (1.2 rkm/d). Individual growth rates were calculated for the DET HOR group (no BC TR fish were recaptured); those values ranged from 0.192 mm/d to 1.344 mm/d with a mean growth rate of 0.836 mm/d. All of the mortalities of NS tagged fish (N = 35) were captured in the Big Cliff tailrace screw trap operated by ODFW.

Despite earlier downstream movement and greater estimated outmigration success for juvenile Chinook salmon released below Project dams, preliminary counts of adult returns to Willamette Falls for above-dam release groups matched or exceeded those of below-dam groups in all years and both subbasins. These results suggest some survival advantage for fish that rear in and successfully exit Project reservoirs, perhaps conferred through faster growth and greater survivorship at saltwater entry. The age structure of PIT-tagged adult salmon that have returned to date suggest there are no consequential differences between the release groups (within a basin) or among other salmon sampled at hatcheries and in the course of spawning surveys. However, ages for MFW returns of PIT-tagged fish appeared to be somewhat overrepresented for age-3 fish and underrepresented for age-5 fish. We emphasize that current adult return data are preliminary and do not yet include all age classes for many of the release groups.

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Introduction

In 1999, the Upper Willamette River (UWR) spring Chinook salmon *Oncorhynchus tshawytscha* Evolutionarily Significant Unit (ESU) was listed as threatened under the U.S. Endangered Species Act (NMFS 1999) and this status was reaffirmed in 2005 (NMFS 2005). Historically among the most productive of the ESU, the Middle Fork Willamette River (MFW) population suffered a precipitous decline during the past century, primarily caused by impacts from Willamette Valley Project (WVP) dams that block adult migrations to historical spawning grounds (Hutchison et al. 1966; NMFS 2008; Keefer et al. 2010). The National Marine Fisheries Service (NMFS) concluded in their 2008 Willamette Project Biological Opinion (BiOp) that the continued operation and maintenance of the WVP would jeopardize the continued existence of UWR Chinook salmon and winter steelhead *O. mykiss* (NMFS 2008). Reasonable and Prudent Alternatives (RPAs) 4.12.2 and 4.12.3 in the BiOp, among others, address downstream fish passage concerns.

Four WVP dams, operated by the U.S. Army Corps of Engineers (USACE), are present in the MFW subbasin (Figure 1). The MFW watershed encompasses 3,509 km^2 and joins the mainstem Willamette River at river kilometer (rkm) 299. Transport and release of adult Chinook salmon into historical MFW spawning grounds above Dexter and Lookout Point (LOP) reservoirs began in 1993 (NMFS 2008). Although these actions were originally intended to provide forage for native bull trout *Salvelinus confluentus* (Johnson and Friesen 2010), the ancillary benefit of augmenting natural production of Chinook salmon in the subbasin soon became a priority (NMFS 2008). Successful spawning above LOP Reservoir was particularly encouraging in light of high pre-spawn mortality and low egg survivorship observed below Dexter Dam (McLaughlin et al. 2008; NMFS 2008; Keefer et al. 2010). However, major challenges accompanied this novel approach towards recovery. For example, high but variable rates of pre-spawn mortality were observed for fish released above LOP Reservoir (Keefer et al. 2010). Perhaps most importantly, downstream passage through LOP and Dexter dams is thought to cause unacceptably high levels of juvenile mortality (NMFS 2008).

Similar to LOP and Dexter dams on the MFW, the construction of Detroit and Big Cliff dams (Figure 2) on the North Santiam River (NS) blocked access to an estimated 71% of historic Chinook salmon spawning habitat (Mattson 1948). The NS watershed encompasses 1,980 km^2 and flows into the Willamette River at rkm 174 after joining the South Santiam River. The Oregon Department of Fish and Wildlife (ODFW) began outplanting adult hatchery Chinook salmon above Detroit Dam in 2000 and recent studies have confirmed that natural production occurs there (Monzyk et al. 2011; Romer et al. 2012; Romer et al. 2016). As with juvenile Chinook salmon that outmigrate from habitats above LOP Reservoir, fish from the upper NS must pass through two WVP reservoirs and dams (Detroit and Big Cliff) before reaching the mainstem Willamette River. Little is known about the risks associated with reservoir and dam passage on the NS. However, research by Normandeau Associates, Inc. (2010) found that passage through the hydroelectric turbines of Detroit Dam resulted in significantly higher mortality for rainbow trout than other at-dam passage routes. Coded-wire tag data demonstrated that juvenile Chinook salmon released into Detroit Reservoir were generally recovered at lower rates (as adults) than those released below Big Cliff Dam, though direct comparisons were hindered by differences in liberation date and fish size (ODFW, unpublished data).

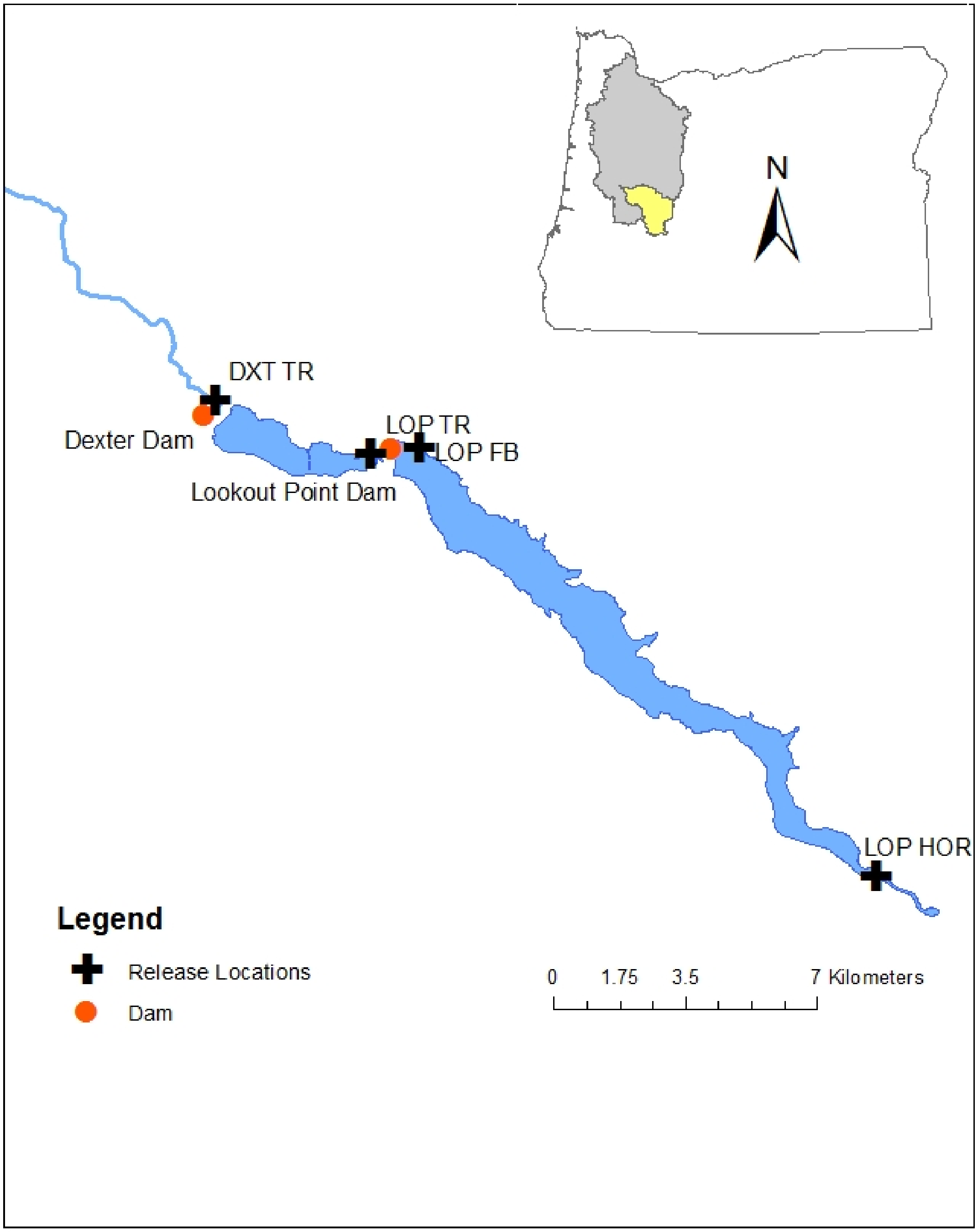

Figure 1. The Middle Fork Willamette River and reservoirs associated with US Army Corps of Engineers-operated dams. Arrows indicate juvenile Chinook salmon release sites for 2014: LOP HOR=Lookout Point head of reservoir, LOP FB = Lookout Point Dam forebay, LOP TR = Lookout Point Dam tailrace and DXT TR = Dexter Dam tailrace.

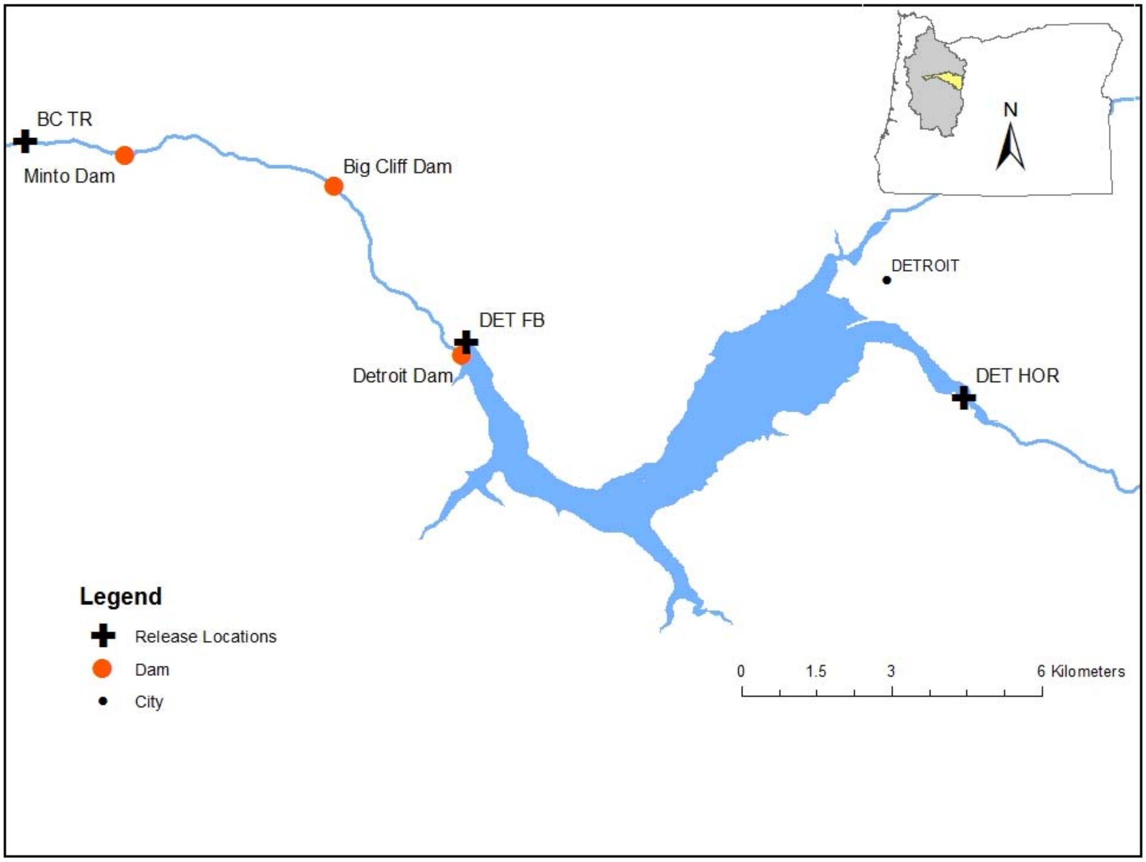

Figure 2. The North Santiam River and reservoirs associated with US Army Corps of Engineers-operated dams. Crosses indicate planned juvenile Chinook salmon release locations for 2015; DET HOR=Detroit head of reservoir, DET FB=Detroit Dam forebay, and BC TR=Big Cliff Dam tailrace. Due to drought conditions (elevated water temperatures and low reservoir elevation) fish designated for DET FB were released at DET HOR. The Stayton Canal and Upper Bennett Dam tag detection sites were located 42 and 39 rkm downstream of Minto Dam, respectively.

Although adult collection, transport and release appear to provide a means for re-establishing natural Chinook salmon production above WVP dams, juvenile downstream passage conditions at LOP, Dexter, Hills Creek (HCR), Detroit, and Big Cliff dams represent a potentially serious threat to outmigrating juvenile salmonids in the NS and MFW subbasins (NMFS 2008). Currently, fish must pass through precarious hydroelectric turbines or regulating outlets (Čada 2001; Muir et al. 2001; Ferguson et al. 2006). In addition, known and potential predators of juvenile salmonids, including northern pikeminnow *Ptychocheilus oregonensis*, largemouth bass *Micropterus salmoides*, walleye *Sander vitreus*, rainbow trout, and cutthroat trout *O. clarkii* are present in Project reservoirs and may represent a substantial risk (Monzyk et al. 2011; Monzyk et al. 2012). Diet samples collected from crappie (*Pomoxis* spp.) in HCR and LOP reservoirs suggested high levels of predation on PIT-tagged fish released for this study in 2012 (Brandt et al. 2016). Residualism of Chinook salmon in WVP reservoirs may also disrupt natural life histories (Romer and Monzyk 2014) and elevate risks during at-dam passage through size-dependent turbine or spill mortality. Recognizing these potential threats, NMFS (2008) recommended that Action Agencies assess juvenile fish passage through WVP reservoirs (RPA 4.10) and dams (RPA 4.11), as initial steps toward assessing and improving juvenile downstream passage.

One alternative to direct passage through reservoirs and dams is to collect juvenile fish at the head of reservoirs and transport them below dams for release. The effectiveness of such an approach in the Willamette Basin, relative to at-dam passage, is unknown. Accordingly, NMFS (2008) recommended that the Action Agencies work to assess the feasibility of collecting juvenile Chinook salmon at the head of WVP reservoirs for subsequent transport and release below dams and "plan, design, build, and evaluate a prototype head-of-reservoir juvenile collection facility above either Lookout Point or Foster reservoir", with these actions being preceded by "feasibility studies" (RPA 4.9). NMFS (2008) further stated that the "Action Agencies will investigate the feasibility of improving downstream fish passage at Lookout Point Dam," beginning "no later than 2012" (RPA 4.12.2) and "investigate the feasibility of improving downstream fish passage at Detroit Dam", beginning "no later than 2015" (RPA 4.12.3). However, collection, transport and downstream release of juvenile salmon could present new risks and challenges. For example, Keefer et al. (2008) provided convincing evidence that when juvenile salmon are subjected to collection and transport, they tend to stray at higher rates during adult spawning migrations. Head-of-reservoir collection and release operations would also likely place juvenile salmonids in highly degraded rearing habitats below dams (NMFS 2008), where mortality might exceed that of reservoir rearing and at-dam passage.

This study was developed to compare the behavior, performance, and survival of hatchery Chinook salmon that pass through USACE reservoirs and dams with those that are released below the dams. This information can be used to estimate the benefits of a head-of-reservoir collection and transport scenario whereby fish are transported around the dams and reservoirs as opposed to the *status quo* of unassisted passage through the projects. Our study is designed to assess the effectiveness of alternate passage routes on the MFW and NS rivers, as these may influence outmigration behavior and survivorship. Specifically, we will measure and report on the effects that LOP, Dexter, HCR, Detroit, and Big Cliff reservoirs and dams have on Chinook salmon outmigration behavior and survivorship, as contrasted with downstream passage that does not involve these migration barriers. We will determine the effectiveness of these passage options through estimates of successful outmigration past Willamette Falls and survivorship to adulthood. Results from this research will provide valuable information for assessing the feasibility and development of head-of-reservoir collection and at-dam passage facilities and address RPA 4.10 (NMFS 2008), which states that, "The Action Agencies will, in coordination with and review by the Services, assess juvenile fish passage through the following Project reservoirs: 1) Cougar, 2) Lookout Point and Dexter, 3) Detroit and Big Cliff, 4) Green Peter and Foster, 5) Fall Creek, 6) Hills Creek". This research also addresses RPA 4.11, as it will "assess passage survival and efficiency through all available downstream routes" of Lookout Point, Dexter, Detroit, and Big Cliff dams. Finally, our research will generate basic information regarding survivorship and outmigration of juvenile Chinook salmon released below WVP dams, thereby providing requisite information for RPA 4.9 (NMFS 2008). This report primarily addresses juvenile salmon released in 2015 and adult returns of tagged fish in previous years. Movement patterns, growth rates and other information relating to tagged juvenile fish released in previous years are presented or referenced in this report for purposes of comparison, but described in detail by Brandt et al. (2016) and Johnson et al. (2016).

Study Objectives

1. Estimate the effect that passage through WVP dams and reservoirs has on outmigration success (counts) and rate (distance/time) by juvenile Chinook salmon in the NS and MFW rivers.
2. Estimate the effect that passage through WVP dams and reservoirs has on survivorship to adulthood for juvenile Chinook salmon in the NS and MFW rivers.
3. Where possible, determine growth rate of recaptured, PIT-tagged Chinook salmon and describe differences in growth among release groups (by subbasin).
4. Where possible, describe the fate of PIT-tagged and CWT fish (e.g. lost to predation, captured in fisheries).

Methods

We PIT tagged juvenile hatchery Chinook salmon and released them at locations above and below WVP dams to estimate the separate effects from reservoir and at-dam passage on outmigration timing, success and, ultimately, survivorship to adulthood. This approach was chosen to provide information relevant to alternate downstream passage strategies (i.e., HOR collection, transport and below-dam release vs. volitional passage) for Chinook salmon produced naturally above WVP dams. Specific release locations for 2015 are provided in Table 1 and indicated in Figure 2.

Tagging and Releases

Although our study was designed to provide information relevant to the downstream passage of naturally-produced juvenile salmon, we used sub-yearling, hatchery-origin Chinook salmon for all releases due to the predictable availability of large numbers of fish. Though hatchery- and natural-origin Chinook salmon in our study area are genetically similar (Johnson and Friesen 2014), differences in the morphology, life history, and behavior are known to exist (Billman et al. 2014). We assumed that for the purposes of this study, hatchery-origin fish were adequately similar to natural-origin fish.

Table 1. Information for juvenile hatchery spring Chinook salmon released into the North Santiam Rivers on 6 August 2015. Release locations were Detroit head of reservoir (DET HOR) and Big Cliff Dam tailrace (BC TR). AD = adipose fin clip; PIT = passive integrated transponder.

Release Site Name	Release Location	Release Number	Mark and Tag
Hoover Boat Ramp	DET HOR	65,981	AD PIT
Packsaddle Park	BC TR	32,854	AD PIT

Fish were produced and hand tagged at the Willamette (MFW releases) and Marion Forks (NS releases) hatcheries; all were reared in a common environment with the same water source and fed equal rations of food until tagging commenced. All study fish released in 2015 were tagged with 12-mm PIT tags (Biomark Inc., Boise, ID). Length distributions, condition, tagging methods and other biologically relevant information were recorded by Biomark and are included in the Appendix. Protocols for PIT tagging followed those suggested by Prentice et al. (1990), and all fish released, except those in the MFW in 2011, were fin clipped (adipose fin removed) to indicate they were of hatchery origin.

Fork length (FL) data for all PIT-tagged fish were collected by Biomark staff during tagging. Chinook salmon should be a minimum 65 mm FL for PIT tagging (R. Richmond, Biomark Inc., *personal communication*), which is approximately 25-50% larger than the mean length of naturally-produced spring Chinook salmon in the MFW and NS rivers at time of reservoir entry (Monzyk et al. 2011; Romer et al. 2012). Accordingly, fish released for this study were slightly larger than average for the same cohort of naturally-produced fish present in the study areas. Once fish were tagged, hatchery rearing ponds with known tag groups were assigned release locations. Prior to release, ODFW personnel collected length data from at least 100 fish from each release group and verified PIT tag codes. All shed tags were collected from the rearing ponds holding study fish. Fish were released approximately 7-10 days after tagging.

A total of 98,835 PIT-tagged Chinook salmon were released on 6 August 2015 in the NS. As in previous years, release dates were chosen to follow natural reservoir recruitment and outmigration as closely as possible, within the constraints imposed by hatchery operations, tagging and production (see Brandt et al. 2016 and Johnson et al. 2016). The number of fish released at each location in 2015 (Table 1) was affected by drought conditions and unacceptably high temperatures and reservoir elevation at the Detroit Dam forebay. Fish intended for release at the forebay were instead released at the head of reservoir, which effectively doubled the group size of that release.

Data Collection and Analysis

Here we report only results from subyearling Chinook salmon released into the North Santiam River in 2015, and describe preliminary findings for adult returns from previous years' releases in both the North Santiam and Middle Fork Willamette rivers.

Individual FLs, release dates and locations for all PIT-tagged fish were uploaded to the PIT Tag Information System (PTAGIS; http://www.ptagis.org/) by Biomark shortly after the releases occurred. Tag detection data were primarily collected at Willamette Falls (PTAGIS site SUJ; Willamette rkm 43) and, for recent NS releases, at Stayton Canal and Upper Bennett Dam (PTAGIS sites NSS and NSB). The NSS and NSB sites are 42 and 39 rkm downstream from Minto Dam (Figure 1), respectively. Additional PIT tag detections were recorded at Tryon Creek Mouth (TCM; Willamette rkm 32), lower Columbia River fixed interrogation sites (PD7; Columbia rkm 70) and the NMFS trawl mobile array (TDX) operated near Columbia rkm 75. Schematics of stationary PIT interrogation sites are available through the PTAGIS website (http://www.ptagis.org/). After release, data for some PIT-tagged fish (i.e. capture date, FL, location) were collected and reported to PTAGIS by ODFW, USACE and other field research crews that encountered them in the Willamette and lower Columbia rivers during the course of their work. These data allowed us to estimate growth and movement rates. In some cases, mortalities from depredation were recorded.

On 3 January 2017 we queried the PTAGIS database for information from PIT tag detections at SUJ and the Willamette Falls adult fishway (PTAGIS site WFF). We used these data to evaluate outmigration success and timing for juveniles released in 2015 and survival to adulthood for Chinook salmon released as juveniles in 2011-2014. To determine if successful outmigration was related to fish size, we used a two-sample Kolmogorov-Smirnov (ks) test to compare the FL distributions of fish in each release group with those of the same group detected at Willamette Falls. We plotted the cumulative and daily number of PIT tag detections at Willamette Falls (through time) to provide a visual representation of juvenile outmigration success and timing for each release group, and we used pairwise *z*-tests to compare the proportions of fish detected at Willamette Falls for each release group. In addition, we expanded raw PIT tag detections at Willamette Falls to provide estimates of total juvenile outmigration past that site using an expansion equation, which accounts for the effects of variable flow on detection efficiencies at Willamette Falls (Schroeder et. al. 2016). Detections at Willamette Falls were also used to estimate movement rates (rkm/d post-release) and evaluate possible dam and reservoir effects on migration timing. Movement rates were calculated as the distance (rkm) traveled from release location to detection at the falls, divided by the number of days at large between release and detection. Shapiro-Wilk test results indicated movement rate data were non-normal or lacked homogeneity of variances (or both) among all release groups; we therefore used Mann-Whitney rank sum tests to evaluate differences among release groups.

Research activities not associated with this project, particularly those by ODFW that used gillnets in reservoirs or screw traps in the rivers, captured and, in some cases, incidentally killed study fish. Biometric data for these captures were often collected, uploaded to PTAGIS and used here to generate growth rate estimates (FL mm/d). We estimated growth rates by dividing the difference between FLs on the day of tagging and day of capture (or mortality) by the number of days at large. We plotted individual growth rates against days at large to investigate differences in growth rate among release groups in each subbasin.

Using data for PIT tag detections in the adult fishway at Willamette Falls, we compared the number of adult returns for release groups within years and subbasins. Because these adult return data are preliminary and do not yet include expected returns for all adult age classes, we did not subject them to formal statistical analyses. Nevertheless, some emergent patterns were present.

In all cases, we performed statistical analyses to compare metrics for release groups only within release years and subbasins, and we used an *a priori* critical value of $\alpha = 0.05$ to qualify the significance of all test results. We used SigmaPlot version 12.5 (Systat Software, San Jose, CA) and S+ v.8.2 (TIBCO Spotfire, Inc.) software for all statistical analyses and to construct figures.

Results

Detections of juvenile Chinook salmon at Willamette Falls

We reiterate that the results presented here are specific to subyearling Chinook salmon released into the North Santiam River in 2015, and to adult returns from previous years' releases in both the NS and MFW rivers.

The median FL of all PIT-tagged fish released into the NS in 2015 was 81 mm (N = 98,835), with a median FL of 81 mm for fish released in the BC TR (N = 32,854), and 81 mm for fish released at DET HOR (N = 65,981) (Table 2). The median fork lengths of fish subsequently detected at Willamette Falls were similar to those of the release groups (BC TR median 80 mm, N = 409; DET HOR median 82 mm, N = 868), yet the length distributions differed significantly between fish released and detected for both the BC TR (ks = 0.0955, $P = 0.0012$) and DET HOR (ks = 0.0484, $P = 0.0355$) groups (Figures 3 and 4).

Table 2. Median and mean fork lengths (FL) at time of tagging for all juvenile hatchery spring Chinook salmon released into the North Santiam River in 2015, and of the subset subsequently detected at Willamette Falls. Release locations were Detroit head of reservoir (DET HOR) and Big Cliff Dam tailrace (BC TR).

	Released FL (mm)					Detected FL (mm)				
Release Location	*N*	Mean	SE	Median	Range	*N*	Mean	SE	Median	Range
BC TR	32,854	81	0.03	81	62-178	410	80	0.24	80	66-96
DET HOR	65,981	81	0.02	81	61-116	870	82	0.18	82	64-98

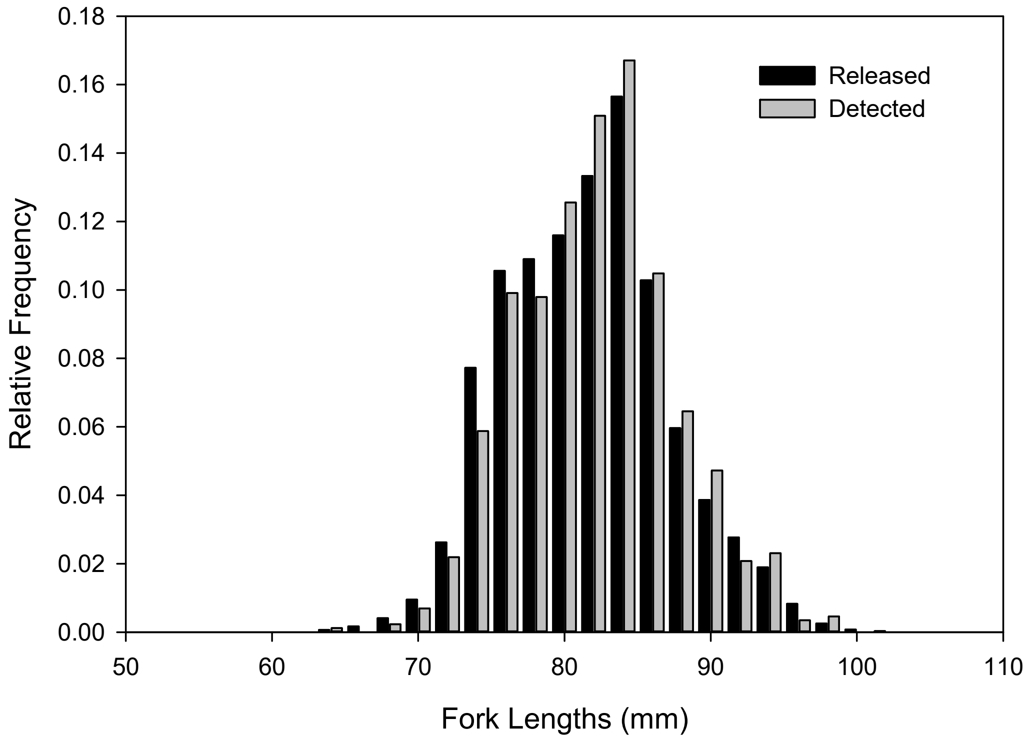

Figure 3. Relative fork length frequencies for juvenile spring Chinook salmon released in 2015 at the head of Detroit Reservoir (DET HOR) and of those subsequently detected at Willamette Falls.

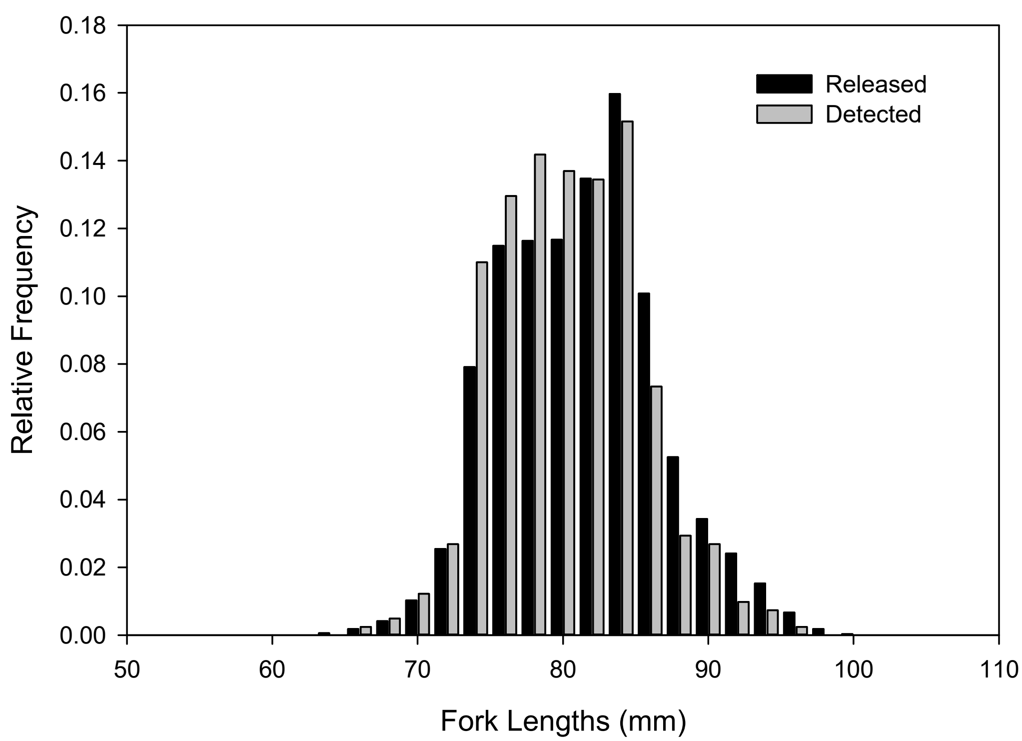

Figure 4. Relative fork length frequencies for juvenile spring Chinook salmon released in 2015 at Big Cliff Dam tailrace (BC TR) and of those subsequently detected at Willamette Falls.

From the 2015 release groups, a total of 1,277 (N = 409 BC TR; N = 868 DET HOR) raw detections occurred at Willamette Falls between 1 September 2015 and 22 July 2016 (Table 2; Figures 5 and 6). The proportions of BC TR and DET HOR released fish that were detected at Willamette Falls were not significantly different in pairwise comparisons ($P < 0.371$), with similar proportions observed for the BC TR group (0.0125) and the DET HOR group (0.0132) (Table 3). The ratio of DET HOR to BC TR detections at Willamette Falls (2.1:1) could largely be explained by the fact that twice as many fish were released at DET HOR. Peak daily detections at Willamette Falls were similar for both the BC TR and DET HOR release groups and occurred on 3 November 2015 (N = 35) and 13 November 2015 (N = 96), respectively (Figure 6). In contrast, the median detection date differed between the two release groups and occurred on 7 February 2016 for the BC TR group and 17 November 2015 for the DET HOR group, providing evidence that fish from the BC TR group spent a considerable amount of time rearing in either the Santiam or mainstem Willamette River (Figure 6).

We expanded the raw detections of juvenile Chinook salmon at Willamette Falls to account for the effects of variable flow on detection efficiency and provide estimates of total juvenile outmigration past that site. Using the expansion equation of Schroeder et al. (2016), an estimated 12,670 (N = 7,449 BC TR; N = 5,221 DET HOR) of the 99,705 tagged fish (12.7%) survived to Willamette Falls (Figure 7). A significantly larger proportion of the BC TR group (0.227) was estimated to have passed Willamette Falls relative to the DET HOR group (0.079) ($P < 0.001$; Table 3). After expansion, the ratio of BC TR to DET HOR fish was 1.4:1 (numerically) and 2.87:1 (proportionally). Peak daily passage at Willamette Falls, estimated from the expanded detections, varied temporally between the groups, occurring on 7 December 2015 for the DET HOR fish and 29 January 2016 for the BC TR fish. The peak number of detections was 318 for both groups (Figure 8).

Juvenile Chinook salmon released into the NS in 2015 were also detected at the Stayton Canal (NSS) and upper Bennett Dam (NSB) PIT tag interrogation sites. The BC TR group was detected more frequently (n = 4,981) at these sites than the DET HOR group (n = 2,050) (Figure 9). The proportions for each release group detected at NSS-NSB (combined) were BC TR = 0.1516 and DET HOR = 0.0301. Peak daily detections at NSS-NSB were different for the BC TR and DET HOR groups and occurred on 13 August 2015 and 18 November 2015, respectively. Median detection date differed between the two release groups and occurred on 23 August 2015 for the BC TR group and 18 November 2015 for the DET HOR group (Figure 10).

Eighteen additional PIT tag detections occurred at other sites, including three in the WFF (BC TR = 2; DET HOR = 1); these were likely outmigrating juveniles. The DET HOR fish was detected on 26 November 2015 and the BC TR fish were both detected in March 2016. Ten fish (BC TR = 3; DET HOR = 7) were detected in the Columbia River TWX array, all in spring 2016. Four BC TR fish were detected at the Columbia River estuary fixed array PD7 in March 2016. Two fish (BC TR = 1; DET HOR = 1) were detected at TCM in the lower Willamette River in January 2016. A single DET HOR fish was detected in two Bonneville fish ladder arrays in June 2016; likely a straying mini-jack ascending the adult fish ladder.

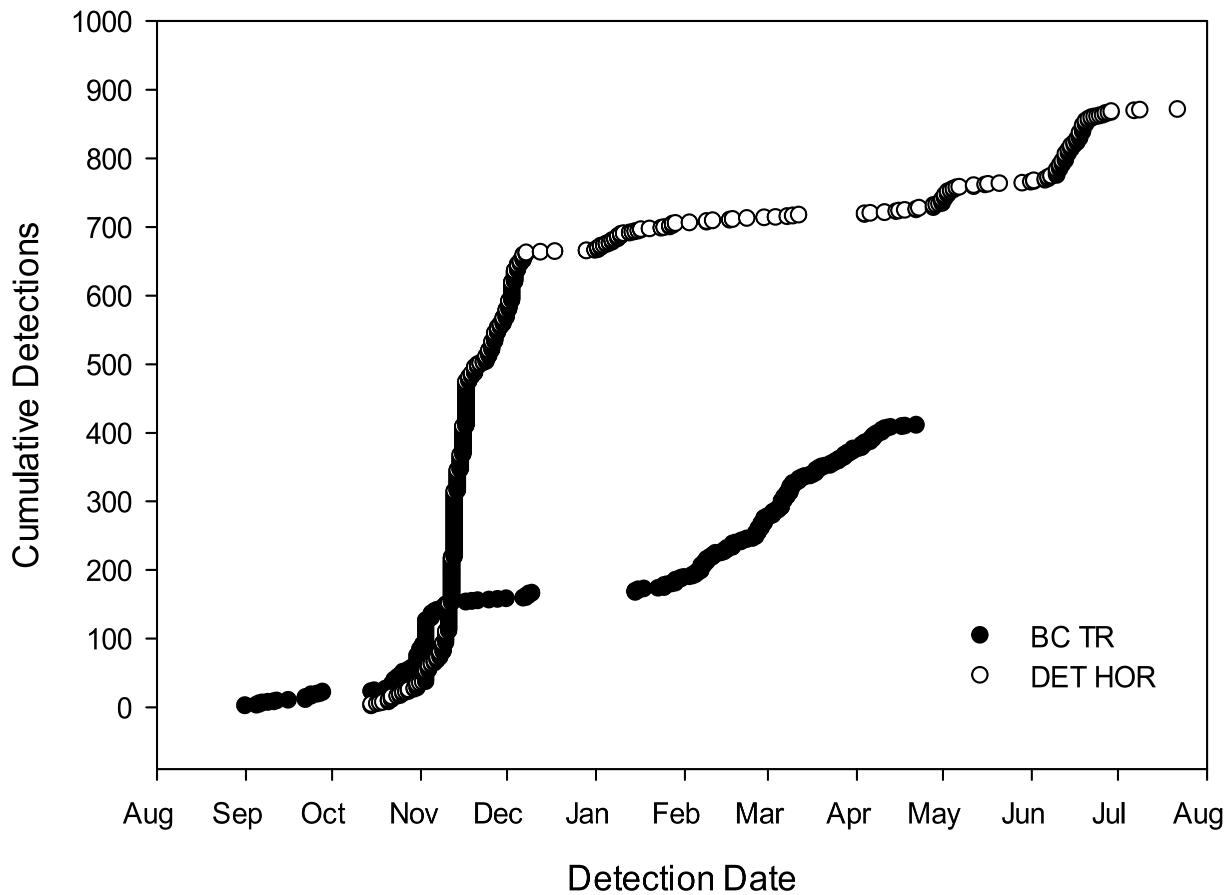

Figure 5. The cumulative number of detections (unexpanded raw count) at Willamette Falls for PIT-tagged juvenile hatchery spring Chinook salmon released on 6 August 2015 into the North Santiam River at Big Cliff Dam tailrace (BC TR) and Detroit head-of-reservoir (DET HOR). Note that unlike previous years (Johnson et al. 2016), release group sizes were disparate (BC TR = 32,854; DET HOR = 65,981) due to poor water conditions at a previously used release site that precluded use of that site in 2015, as described in the text.

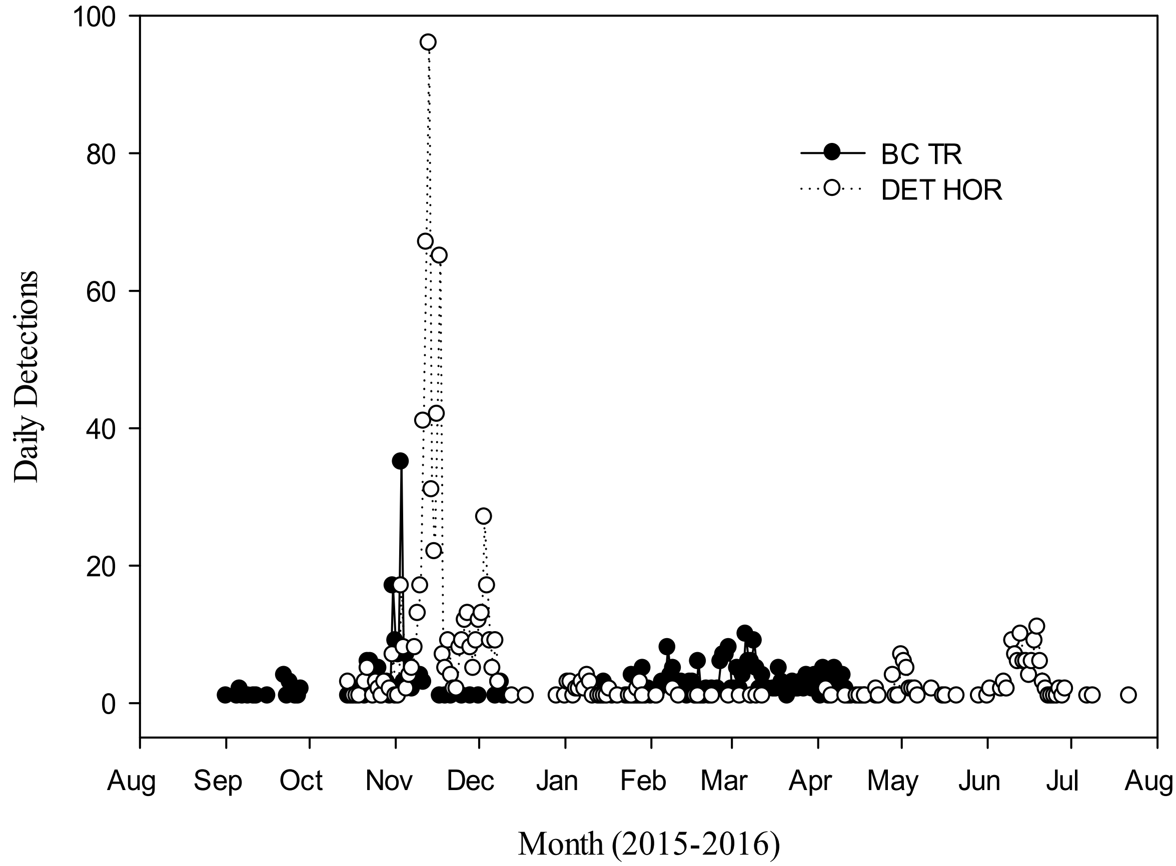

Figure 6. Daily detections (unexpanded raw count) at Willamette Falls of PIT-tagged juvenile spring Chinook salmon released on 6 August 2015 into the North Santiam River at Big Cliff Dam tailrace (BC TR) and Detroit head-of-reservoir (DET HOR). Note that unlike previous years (Johnson et al. 2016), release group sizes were disparate (BC TR = 32,854; DET HOR = 65,981) due to poor water conditions at a previously used release site that precluded use of that site in 2015, as described in the text.

Table 3. The proportions of PIT-tagged juvenile spring Chinook salmon released into the North Santiam River in 2015 detected at (raw count) or estimated (expanded count) to have passed Willamette Falls (SUJ). Release locations were Detroit head of reservoir (DET HOR) and Big Cliff Dam tailrace (BC TR).

Release Location	N Released	Proportion Detected at SUJ	Proportion Estimated at SUJ
DET HOR	65,981	0.013	0.079
BC TR	32,854	0.012	0.227

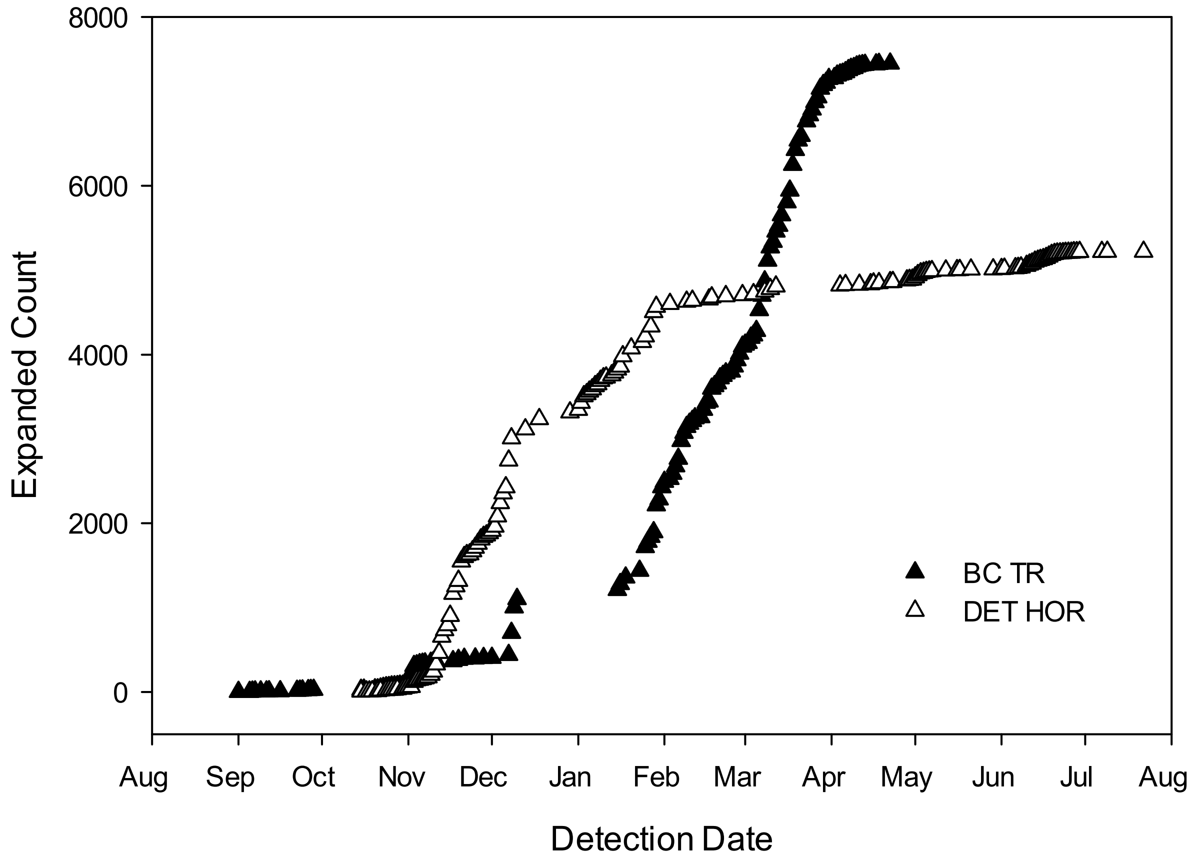

Figure 7. The cumulative number of juvenile hatchery spring Chinook salmon estimated to have passed Willamette Falls (based on expanded PIT tag detections) after release on 6 August 2015 into the North Santiam River at Big Cliff Dam tailrace (BC TR) and Detroit head-of-reservoir (DET HOR). Note that unlike previous years (Johnson et al. 2016), release group sizes were disparate (BC TR = 32,854; DET HOR = 65,981) due to poor water conditions at a previously used release site that precluded use of that site in 2015, as described in the text.

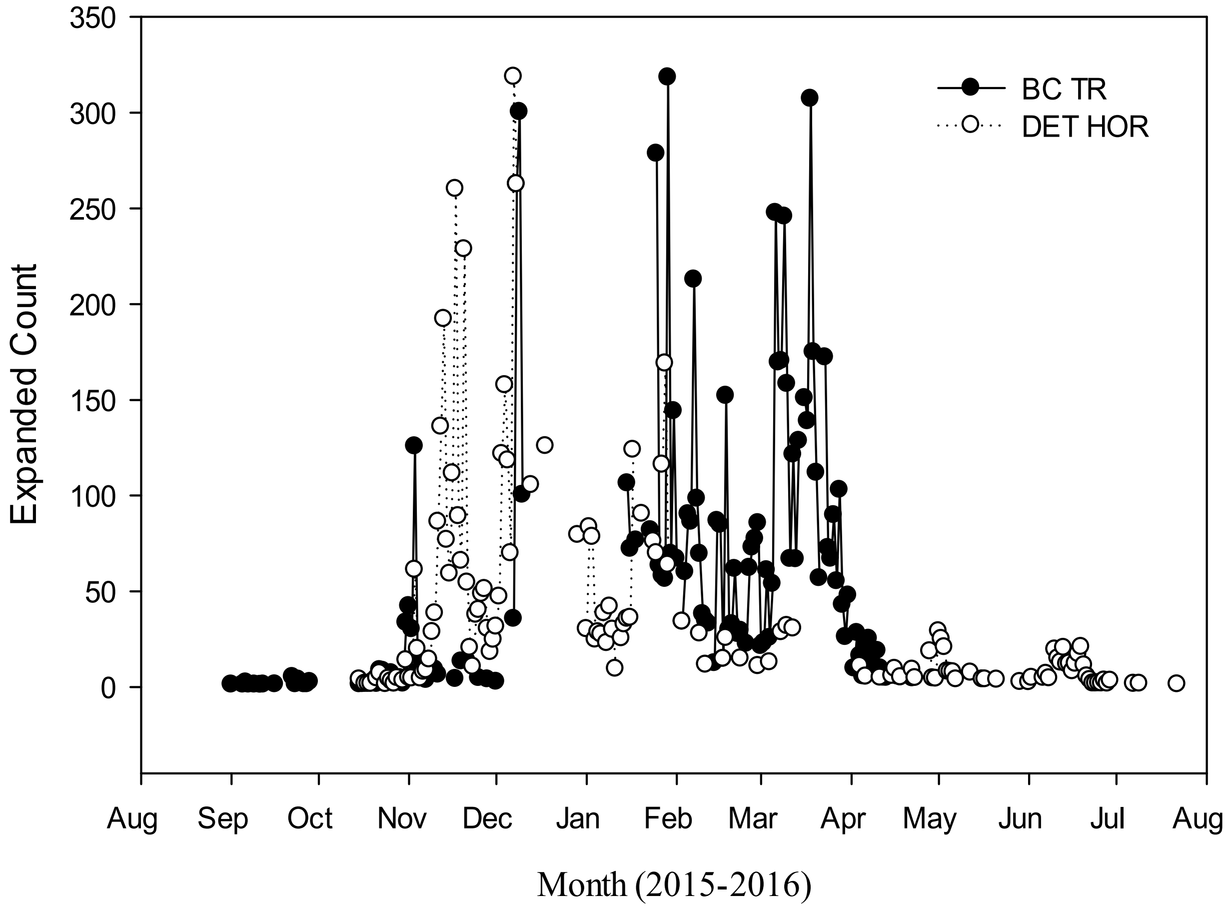

Figure 8. The daily number of PIT-tagged juvenile spring Chinook salmon estimated to have passed Willamette Falls (based on expanded PIT tag detections) after being released on 6 August 2015 at two locations of the North Santiam River; Big Cliff Dam tailrace (BC TR) and Detroit head-of-reservoir (DET HOR). Note that unlike previous years (Johnson et al. 2016), release group sizes were disparate (BC TR = 32,854; DET HOR = 65,981) due to poor water conditions at a previously used release site that precluded use of that site in 2015, as described in the text.

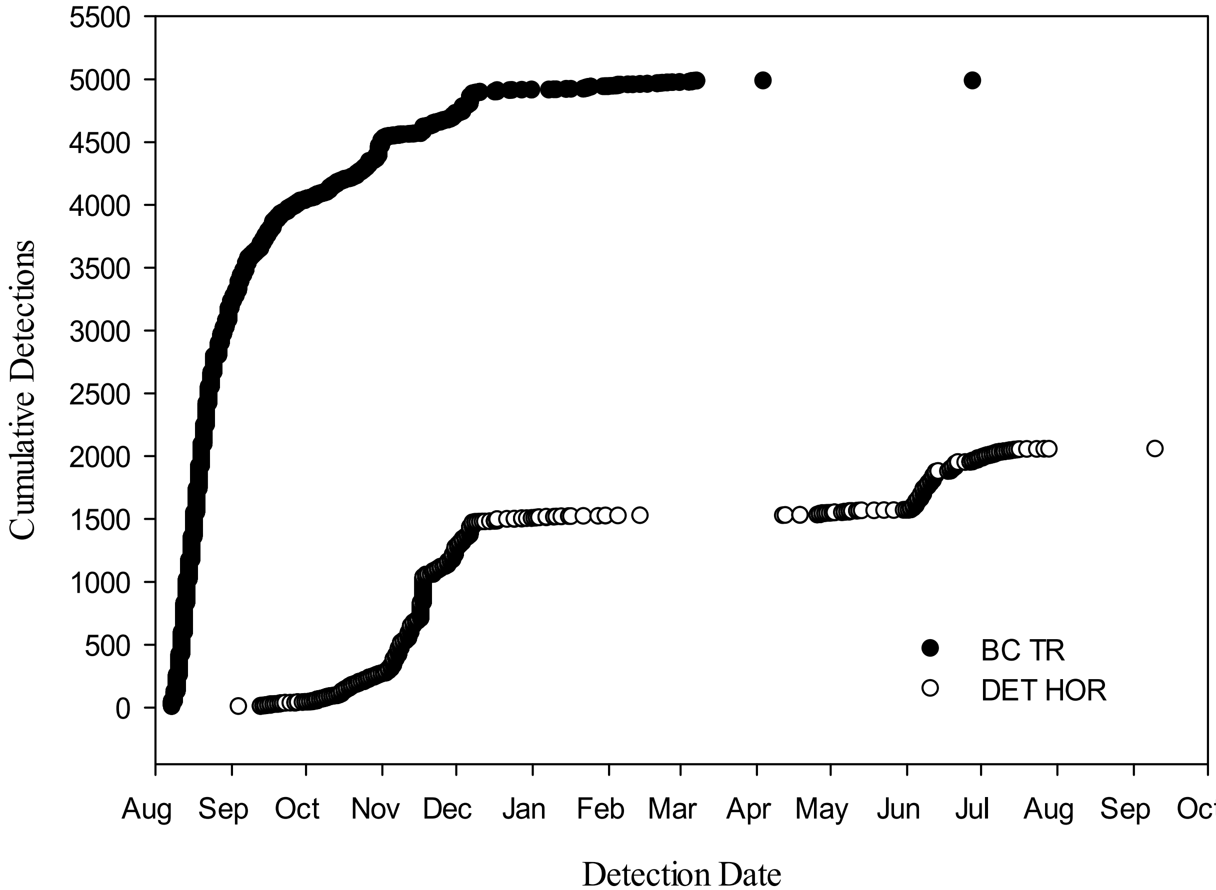

Figure 9. Cumulative detections at Upper Bennett Dam and Stayton Canal for PIT-tagged juvenile Chinook salmon released on 6 August 2015 into the North Santiam River at Big Cliff Dam tailrace (BC TR) and Detroit head-of-reservoir (DET HOR). Note that unlike previous years (Johnson et al. 2016), release group sizes were disparate (BC TR = 32,854; DET HOR = 65,981) due to poor water conditions at a previously used release site that precluded use of that site in 2015, as described in the text.

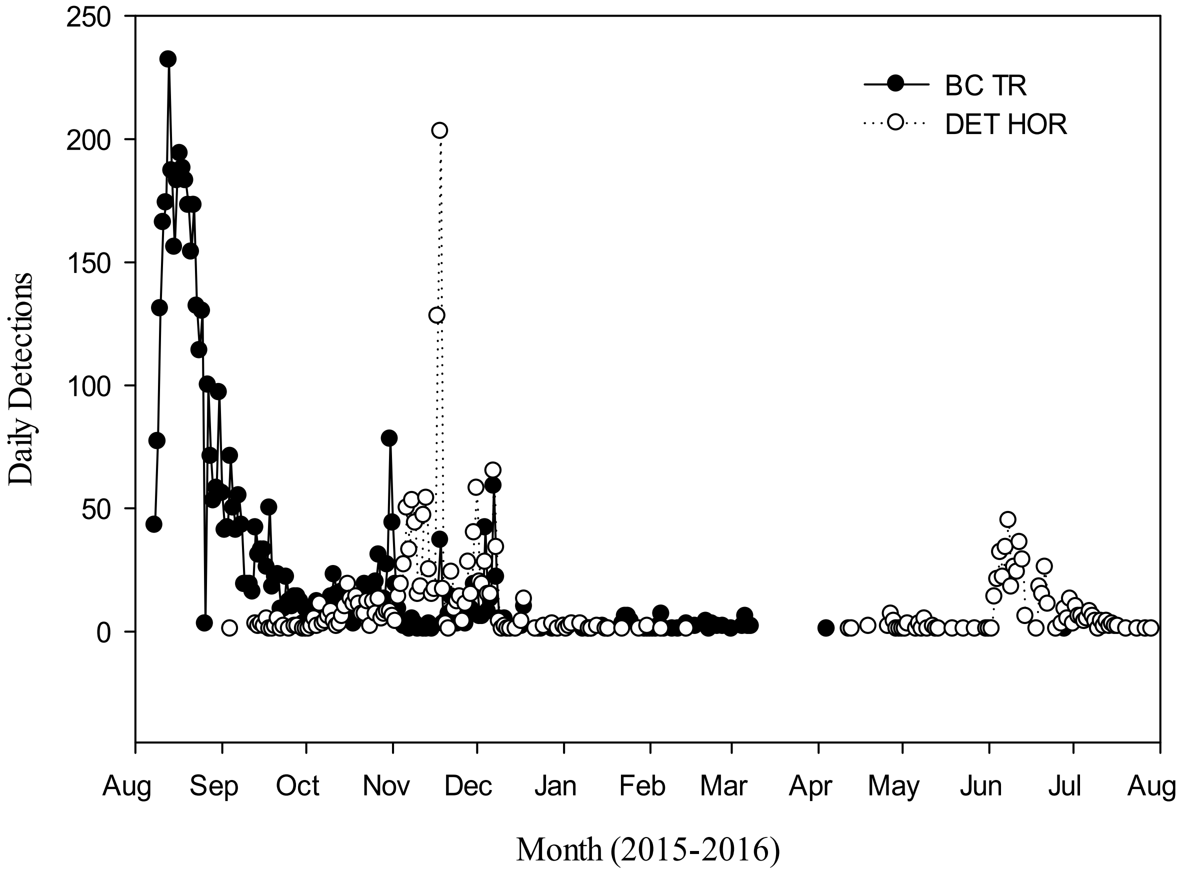

Figure 10. Daily detections at Upper Bennett Dam and Stayton Canal for PIT-tagged juvenile Chinook salmon released on 8 August 2015 into the North Santiam River at Big Cliff Dam tailrace (BC TR) and Detroit head-of-reservoir (DET HOR). Note that unlike previous years (Johnson et al. 2016), release group sizes were disparate (BC TR = 32,854; DET HOR = 65,981) due to poor water conditions at a previously used release site that precluded use of that site in 2015, as described in the text.

Willamette Falls detections and movement rates

The median travel time for all PIT-tagged juvenile Chinook salmon released in 2015 and subsequently detected at Willamette Falls (SUJ) was 106 d (n = 1,280) with median travel times of 185 d (n = 410) and 103 d (n = 870) for the BC TR and DET HOR released fish, respectively (Table 4; Figures 11 and 12). The median movement rate for fish released at BC TR (1.2 rkm/d) was significantly slower ($P < 0.001$) than that of fish released at DET HOR (2.4 rkm/d) (Table 4).

Additional detections and movement rates

The majority of additional detections of tagged juvenile Chinook salmon occurred at two NS interrogation sites, NSS and NSB. Of the 99,705 fish tagged, 7,031 were detected at these two sites. The median travel rate to NSS-NSB was significantly greater for the BC TR group (2.4 rkm/d), relative to the DET HOR group (0.6 rkm/d) ($P = < 0.001$; Table 5). In contrast to the

Table 4. The mean and median travel times (days) and movement rates (rkm/day), as determined from PIT tag detections at Willamette Falls, for juvenile spring Chinook salmon released into the North Santiam River in 2015. Release locations included Detroit head of reservoir (DET HOR) and Big Cliff Dam tailrace (BC TR). Median movement rates for DET HOR and BC TR groups were significantly different (Mann-Whitney rank sum test; $P < 0.001$).

	Travel time (d)					Movement rate (rkm/d)			
Release Location	N	Mean	SE	Median	Range	Mean	SE	Median	Range
DET HOR	870	141.6	2.60	103.0	70-351	2.1	0.02	2.4	0.69-3.47
BC TR	410	159.6	3.26	185.5	26-260	1.8	0.06	1.2	0.84-8.35

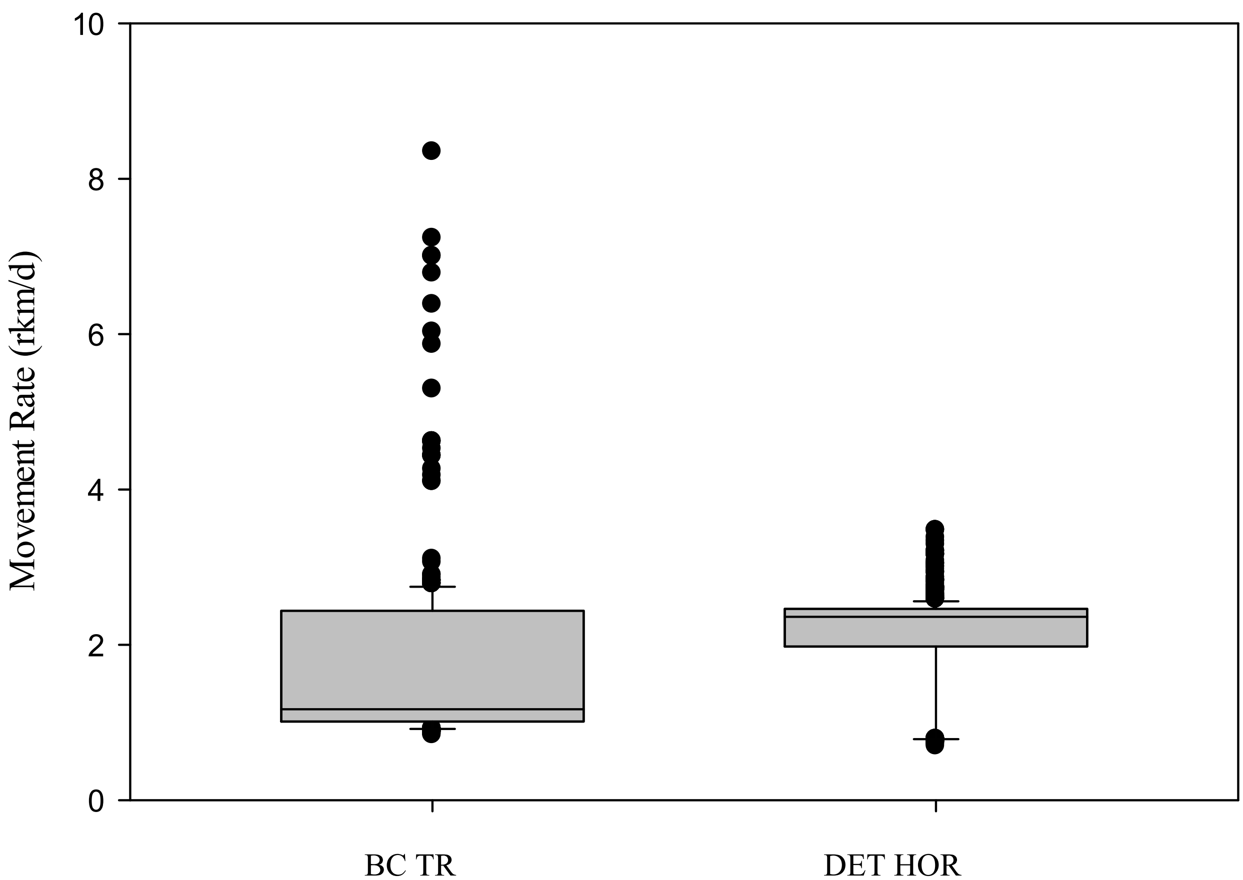

Figure 11. Box and whisker plots depicting downstream movement rates to Willamette Falls for juvenile spring Chinook salmon released into the North Santiam River on 6 August 2015 at Big Cliff Dam tailrace (BC TR) and Detroit head of reservoir (DET HOR). The horizontal line within each box indicates the median rate for each group; the top and bottom borders of the box are the 75th and 25th percentiles (respectively); whiskers are the 90th and 10th percentiles, and the black circles are outliers.

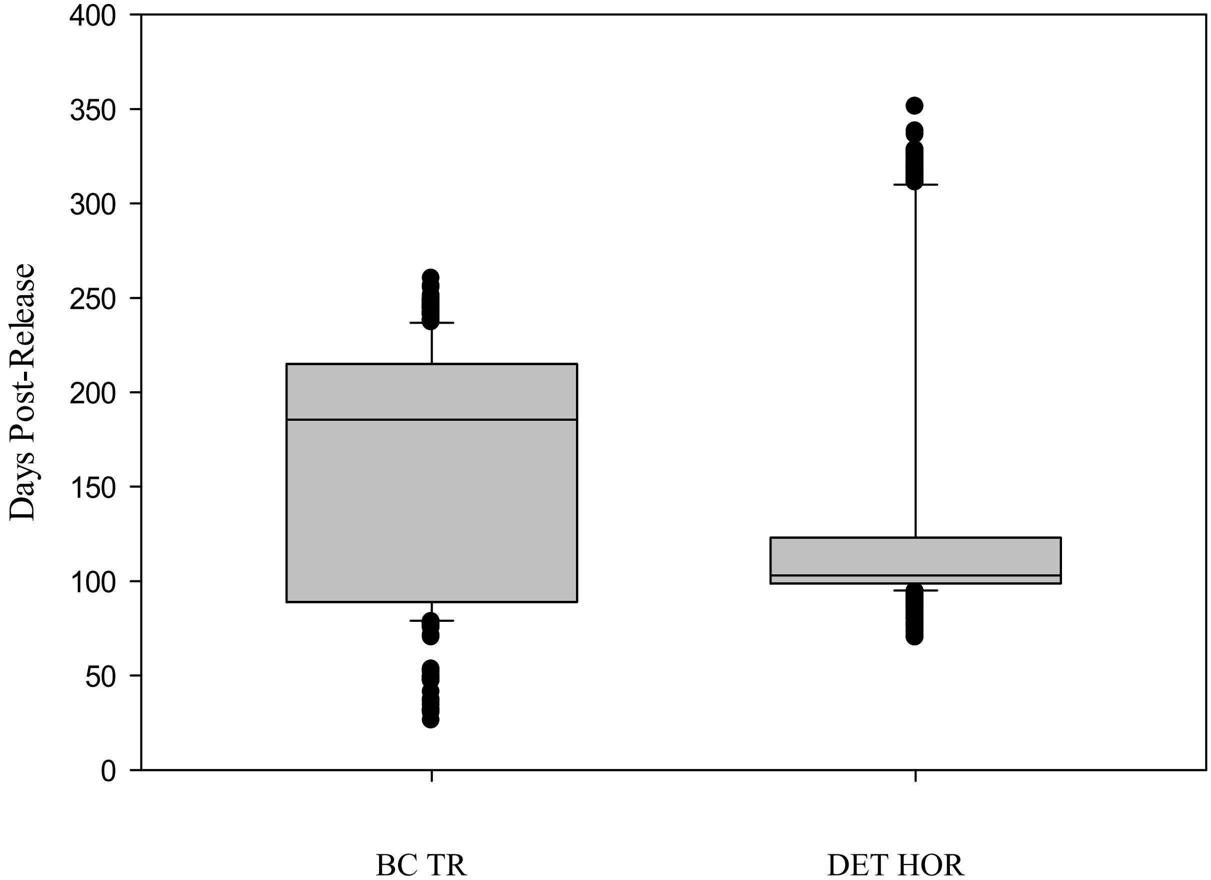

Figure 12. Box and whisker plots depicting detection dates (days post-release) at Willamette Falls of juvenile spring Chinook salmon released into the North Santiam River on 6 August 2015 at Detroit head of reservoir (DET HOR) and Big Cliff tailrace (BC TR). The horizontal line within each box indicates the median rate for each group; the top and bottom borders of the box are the 75th and 25th percentiles (respectively); whiskers are the 90th and 10th percentiles, and the black circles are outliers.

Table 5. Median travel rates (rkm/day) for juvenile Chinook salmon released into the North Santiam River at Detroit head of reservoir (DET HOR) and Big Cliff Dam tailrace (BC TR) in 2015, as determined from PIT tag detections at upper Bennett Dam (NSB) and Stayton Canal (NSS) (PD7). Median travel rates were significantly different (*P* < 0.001) for all pairwise comparisons within rows and columns, except where indicated by a shared superscript.

	NSB		NSS		NSS & NSB	
Release Location	n	Median	n	Median	n	Median
BC TR	344	2.24[a]	4,637	2.35[a]	4,981	2.35[a]
DET HOR	63	0.51[b]	1,987	0.64[b]	2,050	0.64[b]

median travel rates to SUJ, the BC TR group had a faster median travel rate to NSS-NSB. These differences in travel rates to NSS-NSB and SUJ for the BC TR group are likely explained by greater numbers of yearling smolts detected at SUJ (59.8% of detections) than at NSS-NSB (1.5% of detections). However, the percent of yearling smolts for the DET HOR group were similar between SUJ (24% of detections) and NSS-NSB (27%). These data suggest a large portion of the BC TR subyearling Chinook salmon migrated past NSS-NSB to rear in the lower Santiam or mainstem Willamette rivers, then outmigrated past Willamette Falls as yearling smolts, whereas the DET HOR fish likely did not rear extensively in the rivers.

Dam operations

Drought conditions occurred in the spring and summer of 2015, prompting unusual operations at Detroit Dam. When the elevation of Detroit Reservoir elevation is below 470 m, surface spill is not available and all spill occurs through the upper regulating outlet, which is located below the power generating turbines. There was no surface spill from the date of the DET HOR release (6 August 2015) to 23 April 2016. The vast majority of reservoir-released fish detected at Willamette Falls (83% of total detections) occurred prior to April 2016 and had only the turbines or regulating outlets as available exits from the reservoir. On the day of release (6 August 2015), total discharge was 960 cfs and no regulating outlet spill occurred until 3 September 2015 (Figure 13).

Mortalities and Recaptures

Very few mortalities and recaptures were recorded for juvenile Chinook salmon released in the NS in 2015 due to a lack of in-reservoir research activities that previously generated the majority of these data. Nevertheless, 35 mortalities were recorded for the 2015 NS releases (N = 35 DET HOR) from screw trapping operations below Big Cliff Dam. An additional 75 recaptures were recorded, 74 from an ODFW screw trap below Big Cliff Dam, and one from ODFW beach seining surveys in the mainstem Willamette River. All recaptures were from the DET HOR release group.

Recaptures and growth rates

Growth rates were calculated with the limited mortality and recapture data that were available for the 2015 release groups. A total of 107 mortalities and recaptures were recorded for the DET HOR group; none for the BC TR group). Of the 107 records, 106 measurements were from screw trapping operations below Big Cliff Dam, and one was recaptured in the mainstem Willamette River during beach seining efforts. The mean growth rate for DET HOR fish was 0.836 mm/d (range 0.192 - 1.344).

Survival to adulthood

At the time of our data query (3 January 2017), no adults from the 2015 NS releases had been detected, nor were expected until spring 2017. However, Brandt et al. (2015) and Johnson et al. (2016) previously reported results for adult returns of fish released in 2011-2014, from both the MFW and NS subbasins; we update those results here. A total of 333 PIT-tagged Chinook

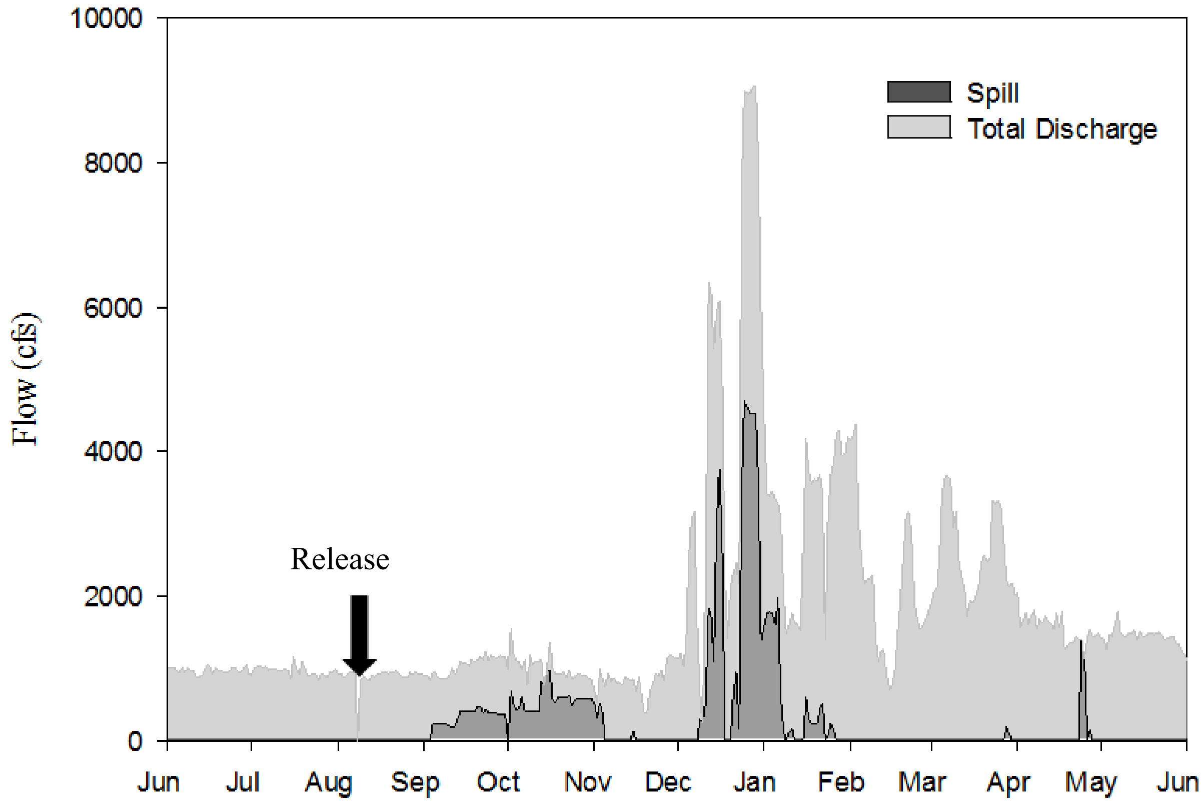

Figure 13. Total discharge (spill + power generation) and spill volume at Detroit Dam in the North Santiam River for 1 June 2015 – 1 June 2016 (data from US Army Corps of Engineers; http://www.nwd-wc.usace.army.mil/cgi-bin/dataquery.pl). Spill occurred only through the regulating outlet, except for 23-26 April 2016, when the spillbay was used. The arrow indicates the date the tagged fish were released above and below the dams.

salmon from our studies in the NS and MFW subbasins ascended the Willamette Falls adult fish ladder (Table 6). The number of adult returns from above-dam releases in the MFW continued to exceed the number of adults returning from the DXT TR group. Of the 97 returning adults that originated from the MFW, 17 were released at DXT TR, one in the LOP tailrace, 21 in the LOP forebay, 40 in the LOP HOR, and 18 at HCR (Table 6).

A similar pattern was observed for adults returning from the NS release groups, though differences between returns for above- and below-dam releases were less pronounced. Among the 236 NS adults detected at Willamette Falls; 76 originated from BC TR, 71 from DET FB, and 89 from DET HOR (Table 6).

Using data from detections at Willamette Falls, we inferred the ages of returning adult salmon released as tagged juveniles and compared these to hatchery and spawning ground age composition data for each basin to investigate potential differences. Age structures for the NS TR and DET HOR release groups were similar to each other and to other collections; all were dominated (51-76%) by age-4 fish, with age 5 (19-49%) and age 3 (0-9%) comprising the

Table 6. Number of adult returns for PIT-tagged Chinook salmon that were released as juveniles into the Middle Fork Willamette and North Santiam rivers, 2011-2014. Release locations were Hills Creek Reservoir (HCR), the head of Lookout Point Reservoir (LOP HOR), Lookout Point Reservoir forebay (LOP FB), the Lookout Point Dam tailrace (LOP TR), Dexter Dam tailrace (DXT TR), the head of Detroit Reservoir (DET HOR), and Big Cliff Dam tailrace (BC TR). For each release year, the set of adult age classes expected to have returned at the time of our data query (3 January 2017) are indicated, and are incomplete for release years 2012- 2014 (at least one age class has not returned).

		Middle Fork Willamette River					North Santiam River		
Release Year	Adult Ages	HCR	LOP HOR	LOP FB	LOP TR	DXT TR	DET HOR	DET FB	BC TR
2011	3,4,5,6	--	2	--	--	2	--	--	--
2012	3,4,5	17	28	--	--	12	32	--	29
2013	3,4	1	10	21	--	3	47	63	43
2014	3	--	--	--	1	--	10	8	4

remainder (Table 7). In the MFW the pattern was similar in that age-4 fish dominated and there were no substantive differences between the ages of DXT TR and LOP HOR fish (Table 8). However, age-3 fish were overrepresented for the PIT-tagged groups relative to the other collections (17% and 18% vs. 1-7%), and age-5 fish were underrepresented (8% and 7% vs. 17-18%). These analyses were done with incomplete cohort data; complete estimates will be possible as additional age classes return in future years (for example, age-6 fish from the 2011 brood year/2012 release year will have returned in 2017).

Table 7. Age structure of adult Chinook salmon released as PIT-tagged juveniles at Big Cliff Dam tailrace (BC TR) and the head of Detroit Reservoir (DET HOR), inferred from year of detection at Willamette Falls, compared to other sources of age structure data from the Middle Fork Willamette basin. Hatchery broodstock includes those fish that were collected by the hatchery and retained for spawning; ages derived from spawning grounds are from carcass recoveries of hatchery and unmarked (wild) fish. All data are from the 2014-2016 run years.

Age	BC TR (N = 29)	DET HOR (N = 32)	Hatchery Broodstock (N = 3,205)	Spawning Ground Hatchery (N = 113)	Spawning Ground Wild (N = 175)
3	7%	9%	3%	0%	7%
4	69%	63%	76%	51%	73%
5	24%	28%	21%	49%	19%
6	--	--	0%	0%	1%

Table 8. Age structure of adult Chinook salmon released as PIT-tagged juveniles at Dexter Dam tailrace (DXT TR) and Lookout Point head-of-reservoir (LOP HOR), inferred from year of detection at Willamette Falls, compared to other sources of age structure data from the Middle Fork Willamette basin. Hatchery broodstock includes those fish that were collected by the hatchery and retained for spawning; ages derived from spawning grounds are from carcass recoveries of hatchery and unmarked (wild) fish. All data are from the 2014-2016 run years.

Age	DXT TR (N = 12)	LOP HOR (N = 28)	Hatchery Broodstock (N = 3,068)	Spawning Ground Hatchery (N = 231)	Spawning Ground Wild (N = 179)
3	17%	18%	1%	3%	7%
4	75%	75%	81%	80%	75%
5	8%	7%	18%	17%	17%
6	--	--	0%	0%	1%

Discussion

Raw (unadjusted) Willamette Falls PIT tag detections of juvenile Chinook salmon released into the North Santiam River in 2015 contrasted with results from previous years (Brandt et al. 2016; Johnson et al. 2016); there was no significant difference in detections at Willamette Falls between the proportion of fish detected from tailrace and head of reservoir release groups. However, this result was strongly influenced by the drought conditions that occurred in the summer of 2015, forcing us to double the number of fish released above the dams relative to the below-dam release. When we estimated the number of outmigrants from PIT detections using the expansion method of Schroeder et al. (2016) to account for river flow, we found that a significantly greater proportion of the BC TR group reached Willamette Falls relative to the DET HOR release group, consistent with our past results (Brandt et al. 2016; Johnson et al. 2016). The large difference in these results could be explained by difference in the median detection dates at Willamette Falls for the BC TR (7 February 2016) and DET HOR (17 November 2015) groups. A larger proportion of the BC TR fish passed Willamette Falls during the late fall and winter months, during higher flows, resulting in greater outmigrant estimates. Additional studies aimed to refine the accuracy of PIT detection efficiency at Willamette Falls under various flow conditions would provide valuable tools to research, such as that presented here. Similar to previous years, the number of unexpanded detections in the lower NS at the NSS-NSB sites was significantly greater for the BC TR group when compared to the DET HOR release group; taken together these results suggest a negative impact to the DET HOR group resulting from some aspect of reservoir and dam passage.

For the second year in a row, movement rates to Willamette Falls were greater for fish released in Detroit Reservoir than for those released below Big Cliff Dam (Johnson et al. 2016). Fish released below the project were detected at higher proportions at Willamette Falls (as yearlings) and therefore included proportionally more individuals that spent a year rearing in the lower Santiam and mainstem Willamette River before migrating toward the Columbia River estuary. This greatly decreased the mean and median movement rates for the BC TR group. Fish released into the tailrace appeared to express more diverse life history pathways, including a yearling outmigration pattern that is less prevalent among reservoir-released fish. The movement rates to the lower NS detection sites, NSS-NSB, contrasted with those to Willamette Falls, whereby tailrace-released fish had a significantly greater movement rate to those sites when compared to the reservoir released fish. Our results suggest that reservoir-released fish tend to be "trapped" in the reservoir during the summer months and would likely experience accelerated growth (ISRP 2011; Monzyk et. al. 2013); they subsequently exit the reservoir in the fall during drawdown operations and migrate Willamette Falls as subyearlings. In contrast, tailrace-released fish appear to disperse to the lower North Santiam and mainstem Willamette rivers relatively soon after release, rearing there (on average) for a longer period of time, before they outmigrate past Willamette Falls as either subyearlings or yearlings. This loss of diversity for the reservoir-released fish poses concerns for the recovery and stability of Upper Willamette spring Chinook salmon, as diversity may likely underpin population resilience amid changing environmental conditions through a "portfolio effect" (Schroeder et. al. 2016). However, delayed migration may present some benefits during low water years, as occurred in the summer of 2015. When freshwater conditions are poor, as in the case of severe drought, delayed migration from reservoirs might provide benefits that outweigh negative reservoir impacts, such as predation, disease, parasitism and high temperatures (Park 1969; Raymond 1988; Monzyk et al. 2015). Nevertheless, improved downstream passage would likely allow spring Chinook salmon to express a wider range of life histories and, therefore, maintain population resiliency and long-term stability.

Relative to their size distribution at release, larger fish were overrepresented in SUJ detections for the HOR group and the smaller fish were overrepresented for the TR group (Figures 3 and 4). This pattern was consistent with observations of rapid growth for fish rearing for extended periods in the reservoirs during warm summer months (ISRP 2011; Monzyk et. al. 2013) before rapidly outmigrating as subyearlings in the fall. Similarly, if the TR fish undertake extended rearing in the subbasin streams and mainstem over a longer period as suggested above, periods of slower growth would occur during cooler months, which may explain the patterns we observed.

Overall, our data suggested that juvenile spring Chinook salmon released below Big Cliff Dam outperformed fish released above Detroit Dam with respect to outmigration success, movement rates, and fate. However, our preliminary data indicate that adult returns of fish released above dams outnumber those of below-dam groups in both subbasins and in all release years. Other studies have documented that lentic reservoir conditions promote faster growth and can increase survivorship to the estuary (Zabel and Achord 2004), and in this case, perhaps increase survivorship to adulthood. Despite recent data that suggest dam passage-related mortality to juvenile salmonids increases significantly with increasing fork length (Taylor 2000), our preliminary adult return data suggest that there may be a survival advantage for the presumably larger reservoir-released fish – assuming they successfully pass the dams.

Faster growth is also known to promote earlier maturation in Chinook salmon (Tattam et. al. 2015) and could potentially reduce population productivity through size-fecundity relationships. To investigate possible effects of reservoir rearing on age structure, we compared the ages of returning adults among release groups and to other known sources of age data in the upper Willamette basin for the 2014-2016 return years. There is currently no evidence to suggest that release location (above- or below-dam) influenced age structure; the proportions of age-3, age-4, and age-5 fish varied only slightly among release locations in the NS and were nearly identical in the MFW. The age structure for study fish in the MFW was somewhat different than those of fish collected at the hatchery or during spawning surveys, but the differences were not large (age-3 fish were overrepresented by 10-17% and age-5 fish were underrepresented by 9-11%) and only 40 PIT-tagged adults were available for this analysis, so we will not speculate on explanations until additional information is available.

We acknowledge that the limited PIT tag detection infrastructure and uncertainties associated with the fate of released fish in our study create difficulties in making definitive determinations about reservoir and dam effects on outmigrating juvenile Chinook salmon. Willamette Falls is a substantial distance from release locations in the MFW and NS, and no specific efforts were made to collect Chinook salmon between release sites and the falls. The NSS and NSB detection sites may prove to alleviate this concern somewhat; we detected a large number of fish at NSS and proportional group detections were similar to those observed at SUJ. However, neither site has been operational for the full duration of the study; their detection efficiencies need to be fully assessed under a range of environmental conditions. An unknown number of fish released above dams may have passed through them unharmed only to later succumb to predation or other stressors during downstream migration in the MFW, NS, or mainstem Willamette rivers. Those would be assumed mortalities from reservoir and dam passage for our analysis, which could inflate perceived effect sizes. The TR releases would also probably experience similar downstream effects, but it is important to recognize that the detection proportions used to evaluate reservoir and dam impacts on juvenile Chinook survival are indices that likely include some mortality not related to dam and reservoir passage.

Another element of uncertainty is the detection efficiency at Willamette Falls; mean river discharge can vary widely among seasons and years, affecting the entrainment and detection of tagged fish at SUJ. Schroeder et al. (2016) developed expansion factors to provide adjusted tag detection counts; we will continue to apply these expansions to future data summaries, and have suggested additional research below that may help confirm their validity. We note that our previous study reports (Brandt et al. 2016; Johnson et al. 2016) did not incorporate the expansion model, which was still in development at the time.

Despite these uncertainties, results from our study continue to provide evidence that WVP dams and reservoirs adversely affect juvenile Chinook salmon survival, movement rate, and timing in the MFW and NS basins. Though our study was not intended to provide robust estimates of juvenile survival, the results have been consistent among years and release locations. Fish released below WVP dams were detected at a higher rate at Willamette Falls in all cases, with the exception of the 2015 drought year, and successful outmigration declined with the number of dams and reservoirs encountered. Based solely on unexpanded detection counts of similarly-sized release groups, the Projects appear to have an effect on outmigration success that ranges from about 35% to >90% depending on release location, with the impact considerably larger in the MFW than the NS. We acknowledge that many sources of bias are possible, but suggest that these would need to be large and have the same directionality every year to substantially influence the patterns we observed.

Future Plans and Recommendations

We again recommend conducting research to estimate the entrainment rate of PIT-tagged fish to the Willamette Falls north fish bypass in relation to river discharge, which could provide retrospective estimates of the total number of fish from each release group that successfully reached Willamette Falls, and verify the expansion calculation of Schroeder et al. (2016), thereby improving juvenile survival estimates. Improvements to the existing PIT-tag detection infrastructure or additional monitoring stations would greatly enhance the usefulness of future releases, especially in providing more robust juvenile survival estimates than is currently possible with the existing infrastructure (see Skalski 2016). Additional detection arrays at or near Project dams would also help determine precisely when tagged fish pass the dams and where mortality is most likely to occur; important factors that could not be fully addressed by this study.

No further releases are planned at this time, and funding is not available to continue analyses or provide a comprehensive completion report. However, juvenile outmigration from the 2015 Chinook salmon releases and 2014-2016 winter steelhead releases is expected continue through at least 2017, and adults will continue to return through at least 2021. ODFW and USACE staff expect to provide summary data from the suite of "paired release" projects as resources allow.

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References

Billman, E. J., L. D. Whitman, R. K. Schroeder, C. S. Sharpe, D. L. G. Noakes, and C. B. Schreck. 2014. Body morphology differs in wild juvenile Chinook salmon *Oncorhynchus tshawytscha* that express different migratory phenotypes in the Willamette River, Oregon, U.S.A. Journal of Fish Biology 85:1097-1110.

Brandt, J. R., T. A. Friesen, M. A. Johnson, and P. M. Olmsted. 2016. Migration, survival, growth, and fate of hatchery juvenile Chinook salmon released above and below dams in the Willamette River Basin. Annual report to the U.S. Army Corps of Engineers, Portland District. Task Order W9127N-10-2-0008-0025. Oregon Department of Fish and Wildlife, Corvallis.

Čada, G. 2001. The development of advanced hydroelectric turbines to improve fish passage survival. Fisheries 26(9):14–23.

Ferguson, J. W., R. F. Absolon, T. C. Carlson, and B. P. Sandford. 2006. Evidence of delayed mortality on juvenile Pacific salmon passing through turbines at Columbia River dams. Transactions of the American Fisheries Society 135:139-150.

Hutchison, J. M., K. E. Thompson, and J. D. Fortune, Jr. 1966. The fish and wildlife resources of the Upper Willamette basin, Oregon, and their water requirements. Oregon State Game Commission, Portland, Oregon. Project F-69-R-3, Job No.1.

Independent Scientific Review Panel (ISRP). 2011-26. Review of the Research, Monitoring, and Evaluation Plan and Proposals for the Willamette Valley Project. Northwest Power and Conservation Council, Portland, Oregon. http://www.nwcouncil.org/library/report.asp?d=648.

Johnson, M. A., and T. A. Friesen. 2010. Spring Chinook salmon hatcheries in the Willamette basin: existing data, discernable patterns and information gaps. Final Report to the U.S. Army Corps of Engineers, Task Order NWPPM-09-FH-05.

Johnson, M. A., and T. A. Friesen. 2014. Genetic diversity and population structure of spring Chinook salmon from the upper Willamette River, Oregon. North American Journal of Fisheries Management 34:853-862.

Johnson, M. A., T. A. Friesen, P. M. Olmsted, and J. R. Brandt. 2016. Migration, survival, growth, and fate of hatchery juvenile Chinook salmon released above and below dams in the Willamette River Basin. Annual report to the U.S. Army Corps of Engineers, Portland District. Task Order W9127N-10-2-0008-0034. Oregon Department of Fish and Wildlife, Corvallis.

Keefer, M. L., C. C. Caudill, C. A. Peery, and S. R. Lee. 2008. Transporting juvenile salmonids around dams impairs adult migration. Ecological Applications 18:1888-1900.

Keefer, M. L., G. A. Taylor, D. F. Garletts, G. A. Gauthier, T. M. Pierce, and C. C. Caudill. 2010. Prespawn mortality in adult spring Chinook salmon outplanted above barrier dams. Ecology of Freshwater Fish 19:361-372.

Mattson, C. R. 1948. Spawning ground studies of Willamette River spring Chinook salmon. Fish Commission Research Briefs, Fish Commission of Oregon 1:21-32.

McLaughlin, L., K. Schroeder, and K. Kenaston. 2008. Interim activities for monitoring impacts associated with hatchery programs in the Willamette basin. USACE funding: 2007. NWPOD-07-FH-02. Oregon Department of Fish and Wildlife, Salem, Oregon.

Monzyk, F. R., J. D. Romer, R. Emig, and T. A. Friesen. 2011. Life-history characteristics of juvenile spring Chinook salmon rearing in Willamette Valley reservoirs. Annual Report to U.S. Army Corps of Engineers, Cooperative Agreement W9127N-10-2-0008, Task Order 0002. Oregon Department of Fish and Wildlife, Corvallis.

Monzyk, F. R., J. D. Romer, R. Emig, and T. A. Friesen. 2012. Life-history characteristics of juvenile spring Chinook salmon rearing in Willamette Valley reservoirs. Annual Report to U.S. Army Corps of Engineers, Portland District, Task Order W912N-10-02-0008-0007. Oregon Department of Fish and Wildlife, Corvallis.

Monzyk, F. R., J. D. Romer, R. Emig, and T. A. Friesen. 2013. Life-history characteristics of juvenile spring Chinook salmon rearing in Willamette Valley reservoirs. Annual Report to U.S. Army Corps of Engineers, Portland District, Task Order W912N-10-02-0008-0007. Oregon Department of Fish and Wildlife, Corvallis.

Monzyk, F. R., T. A. Friesen, and J. R. Romer. 2015. Infection of juvenile salmonids by *Salmincola californiensis* (Copepoda: Lernaeopodidae) in reservoirs and streams of the Willamette River basin, Oregon. Transactions of the American Fisheries Society 144:891-902.

Muir, W. D., S. G. Smith, J. G. Williams, and B. P. Sandford. 2001. Survival of juvenile salmonids passing through bypass systems, turbines, and spillways with and without flow deflectors at Snake River dams. North American Journal of Fisheries Management 21:135-146.

NMFS (National Marine Fisheries Service). 1999. Endangered and threatened species: Threatened status for three Chinook salmon Evolutionarily Significant Units in Washington and Oregon, and Endangered status of one Chinook salmon Evolutionarily Significant Units in Washington; Final rule partial 6-month extension on final listing determinations for four Evolutionarily Significant Units of West Coast Chinook salmon; proposed rule. Federal Register 64(56):14308-14328.

NMFS (National Marine Fisheries Service). 2005. Endangered and threatened species: final listing determinations for 16 Evolutionarily Significant Units of West Coast salmon, and final 4(d) protective regulations for threatened salmonid Evolutionarily Significant Units. Federal Register 70(123):37160-37204.

NMFS (National Marine Fisheries Service). 2008. 2008-2023 Willamette River basin project biological opinion. NOAA's National Marine Fisheries Service, Northwest Region, Seattle, Washington. F/NWR/2000/02117.

Normandeau Associates, Inc. 2010. Estimates of direct survival and injury of juvenile rainbow trout (*Oncorhynchus mykiss*) passing spillway, turbine, and regulating outlet at Detroit Dam, Oregon. Draft Technical Report to the U.S. Army Corps of Engineers, Portland District-Willamette Valley Project, Portland, Oregon.

Park, D. L. 1969. Season changes in downstream migration of age-group 0 chinook salmon in the upper Columbia River. Transactions of the American Fisheries Society 98:315-317.

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, D. F. Brastow, and D.C. Cross. 1990. Equipment, methods, and an automated data-entry station for PIT-tagging. American Fisheries Society Symposium 7:335-340.

Raymond, H. L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River basin. North American Journal of Fisheries Management 8:1-24.

Romer, J. D., and F. R. Monzyk, 2014. Adfluvial life history in spring Chinook salmon from Quartzville Creek, Oregon. North American Journal of Fisheries Management, 34(5), 885-891.

Romer, J. D., F. R. Monzyk, R. Emig, and T. A. Friesen. 2012. Juvenile salmonid outmigration monitoring at Willamette Valley project reservoirs. Annual Report to U.S. Army Corps of Engineers, Cooperative Agreement W9127N-10-2-0008, Task Order 0006. Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Romer, J. D., F. R. Monzyk, R. Emig, and T. A. Friesen. 2016. Juvenile salmonid outmigration monitoring at Willamette Valley project reservoirs. Annual Report to U.S. Army Corps of Engineers, Cooperative Agreement W9127N-10-2-0008, Task Order 0035. Oregon Department of Fish and Wildlife, Corvallis, Oregon.

Schroeder, R. K., L. D. Whitman, B. Cannon, and P. Olmsted. 2016. Juvenile life-history diversity and population stability of spring Chinook salmon in the Willamette River basin, Oregon. Canadian Journal of Fisheries and Aquatic Sciences 73. DOI dx.doi.org/10.1139/cjfas-2015-0314.

Skalski, J. R. 2016. Review of tagging study designs to estimate reservoir passage survival in the Willamette Valley Project. Final Report to U.S. Army Corps of Engineers, Portland District. University of Washington, Seattle.

Tattam, I. A., J. R. Ruzycki, J. L. McCormick, and R. W. Carmichael. 2015. Length and condition of wild Chinook Salmon smolts influence age at maturity. Transactions of the American Fisheries Society 144:1237-1248.

Taylor, G. A. 2000. Monitoring of downstream fish passage at Cougar Dam in the South Fork McKenzie River, Oregon 1998-00. Oregon Department of Fish and Wildlife technical report available at (30 March 2016) http://nrimp.dfw.state.or.us/CRL/Reports/CRTCP/Cougartrap98_00fin_rpt.pdf

Zabel R. W. and S. Achord. 2004. Relating size of juveniles to survival within and among populations of Chinook salmon. Ecology 85:795-806.

APPENDIX: BIOMARK TAGGING REPORT, 2015

PIT-TAG 100,000 JUVENILE SPRING CHINOOK AND 24,000 WINTER STEELHEAD AT MARION FORKS HATCHERY, JUNE 2015

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Introduction

The National Marine Fisheries Service (NMFS) Biological Opinion (BiOp) (2008) requires improved juvenile fish passage by providing either head-of-reservoir collection and transport systems or improved juvenile passage at Willamette Project dams. NMFS BiOp also requires improving flows and water temperatures below Willamette Project dams. There is a paucity of data available on outmigration behavior and survival of spring Chinook salmon rearing above and below Willamette Valley projects. Monitoring marked juvenile spring Chinook salmon (*Oncorhynchus tshawytscha)* can help inform survival and migration timing within and below Willamette Project Reservoirs. Information can be used to better understand the life history of juvenile Chinook salmon, and inform decisions regarding juvenile passage and survival at Willamette Project dams.

In May of 2011, Biomark PIT-tagged approximately 12,000 hatchery juvenile spring Chinook salmon at Willamette Hatchery as a pilot project. In May and July of 2012, Biomark PIT-tagged approximately 175,000 hatchery juvenile spring Chinook at Willamette and Marion Forks Hatchery (150,000 and 25,000, respectively). In 2013, Biomark PIT-tagged approximately 150,000 spring Chinook at Willamette Hatchery and 100,000 spring Chinook at Marion Forks Hatchery. In 2015, Biomark PIT-tagged approximately 100,000 juvenile spring Chinook at Marion Forks Hatchery.

Methods

All tagging was conducted in a self-contained tagging trailer positioned near the raceway holding the fish to be tagged. Water for the trailer was pumped from a raceway or pond nearest the trailer. This water was also used to chill the re-circulating anesthetic water within the tagging trailer. Variation in water temperature between the holding facility and the anesthetic water was maintained at less than 0.5 °C difference.

Biomark followed the PIT-tagging protocols mandated by the U.S. Army Corps of Engineers (USACE), Portland District (CENWP) using the body cavity tagging techniques similar to those described in Prentice et al. (1990). Fish were tagged with 12.5mm 134.2 kHz ISO PIT tags (HPT tags) using preloaded 12-gauge hypodermic needles (Biomark pre-loaded needle BIO12.BPL) fitted onto an injection device (Biomark implant gun MK-25). All fish were tagged with single-use needles to reduce the chance of disease transmission, injuries caused by dull needles, and reduce the number personnel required for the project.

Anesthetic water was changed every two hours. An un-buffered anesthetic (MS-222) was used.

The Biomark tagging crew consisted of 6-8 taggers and 3-4 data collectors (data collectors interrogate each tagged fish, measure fork length and note external signs of disease). The data collectors also tagged fish, as time allowed.

No obviously diseased or injured fish were tagged, including, but not limited to, BKD and pinheads. An attempt was made to only tag fish ≥ 65 mm fork length (FL). Potential anomalous conditions were recorded for each fish that was tagged (i.e., bleeding, dropped, deep tag insertion). All tagged fish were returned to a holding trough or circular ponds via a 3-inch PVC pipe. All undersized fish and fish rejected for physical conditions were returned untagged to the raceway of origin.

At the time of tagging the tag code, fork length, fish condition and treatment group were stored using PITTag3 software [Pacific States Marine Fisheries Commission (PSMFC)]. PIT tag codes were used only one time. During tagging operations any shed tags found in the trough, along with tags removed from mortalities, were scanned into a file and this data was used to "dot–out" tag codes in the tagging files. The tags were then implanted into new fish with the appropriate information recorded.

Tagging files were consolidated and submitted to PTAGIS regional database after tagging. Copies of the data files were also provided to the ODFW technical lead Tom Friesen.

Task 1 – PIT-tag 100,000 subyearling spring Chinook salmon at Marion Forks Hatchery

The objective at Marion Forks Hatchery was to PIT-tag 100,000-hatchery juvenile spring Chinook salmon beginning in late June 2015. Biomark tagged approximately 16,500 fish per day for six days.

The fish to be tagged were held in two circular ponds (C7 and C8). After tagging, the fish were split evenly among three circular ponds (C16, C17, and C18). Each of the three ponds were to have approximately 33,333 PIT-tagged fish.

Task 2 – PIT-tag 24,000 juvenile winter steelhead at Marion Forks Hatchery

The objective at Marion Forks Hatchery was to tag 24,000-hatchery juvenile winter steelhead beginning in late June 2015. Biomark was informed that fewer winter steelhead had been transported to the hatchery and that there would be between 18,000 to 19,000 available for PIT-tagging. Biomark tagged approximately 18,500 winter steelhead, which was all of the available fish.

The fish to be tagged were held in one circular pond (C11). Half of the PIT-tagged fish were placed into pond C9 and the other half were placed into pond C10.

Results

The primary goals of this project to PIT-tag approximately 100,000 juvenile subyearling Chinook salmon at Marion Forks Hatchery and the adjusted goal of approximately 18,500 juvenile winter steelhead at Marion Forks Hatchery were met.

Task 1 – PIT-tag 100,000 subyearling spring Chinook salmon at Marion Forks Hatchery

Biomark implanted PIT tags into a total of 100,173 juvenile subyearling Chinook salmon at Marion Forks Hatchery between 25 June and 30 June 2015 (Table 1). Lengths were recorded for 99.7% of the tagged fish (Table 2). A total of 613 fish were rejected prior to tagging because they were less than 65 mm FL (n=236) or they had obvious signs of disease or injury (n=377). A total of 100,786 fish were handled during the tagging process (Table 1).

A total of 1,356 (1.35%) combined mortality and shed tags were recovered. Of those a total of 23 tags were collected during tagging, of which 18 were re-implanted into fish. A total of 1,333 were collected after tagging and prior to release by hatchery personnel (Table 1).

Task 2 – PIT-tag 24,000 juvenile winter steelhead at Marion Forks Hatchery

Biomark implanted PIT tags into a total of 18,491 juvenile winter steelhead at Marion Forks Hatchery on 24 June 2015 (Table 1). Lengths were recorded for 93.2% of the tagged fish (Table 3). A total of 189 fish were rejected prior to tagging because they were less than 65 mm FL (n=92) or they had obvious signs of disease or injury (n=97). A total of 18,680 fish were handled during the tagging process (Table 1).

A total of 10 (0.05%) combined mortality and shed tags were collected for Task 3 at the time of writing this report. During tagging a total of 10 tags were collected and none of them were reused (Table 1). After the fish have been released hatchery personnel will provide the total number of mortality and shed tags collected between tagging and release.

Discussion

Task 1 – PIT-tag 100,000 subyearling spring Chinook salmon at Marion Forks Hatchery

The Chinook salmon quality at Marion Forks Hatchery was very good. The majority of fish tagged (80.5%) had a fork length between 75mm and 89mm (Figure 1). A very small number of fish were rejected due to being undersize (n=236, 0.23%). Few fish were rejected because of obvious signs of disease or injuries (n=377, 0.37%).

The observed mortality/shedding rate during tagging was low (n=23, 0.023%). However, after tagging and prior to release the fish contracted coldwater disease. This resulted in a large number of mortality and shed tags (n=1,333, 1.33%). Ponds C16 and C17 had similar mortality numbers (n=531 and n=525, respectively) while pond C18 had much lower mortality (n=277).

Task 2 – PIT-tag 24,000 juvenile winter steelhead at Marion Forks Hatchery

The quality of the winter steelhead at Marion Forks Hatchery was good. A majority of the fish (79.9%) had a fork length between 85mm and 114mm (Figure 2). A small number of fish were rejected due to being undersize (n = 92, 0.49%). About the same number of fish were rejected because of obvious signs of disease or deformities (n = 97, 0.52%).

The number of mortality/shed tags collected during tagging was very low (n = 10, 0.05%). While tagging at Marion Forks Hatchery we collected a total of 7 steelhead mortalities. The total post-tagging pre-release mortality and shed tags will be tallied by hatchery personnel after the fish have been released. The releases are expected to take place in November 2015. After the fish have been released this report will be updated to reflect changes in the mortality and shed rate of winter steelhead at Marion Forks Hatchery.

Recommendations

Biomark recommends the following change to the tagging protocol:

1. If possible, allow for a minimum two week recovery time between events (coded-wire tagging/clipping and PIT-tagging) to reduce handling stress on the fish.

Acknowledgements

We would like to acknowledge Chris Boyd and the staff at Marion Forks Hatchery for accommodating us and for their assistance during tagging.

References

Prentice, E. F., T. A. Flagg, C. S. McCutcheon, D. F. Brastow, and D.C. Cross. 1990. Equipment, methods, and an automated data-entry station for PIT-tagging. American Fisheries Society Symposium 7:335-340.

Figures

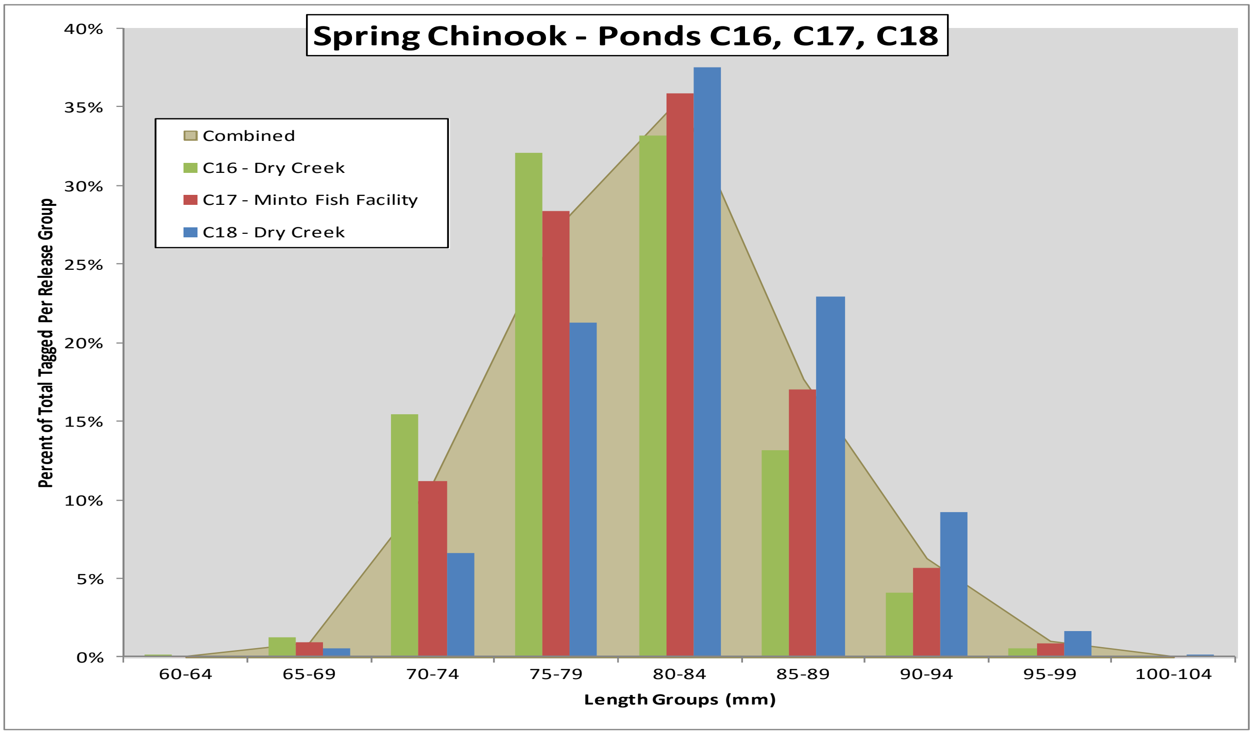

Figure 1. Length frequency of PIT-tagged juvenile subyearling Chinook salmon tagged for Task 1 at Marion Forks Hatchery, June 2015.

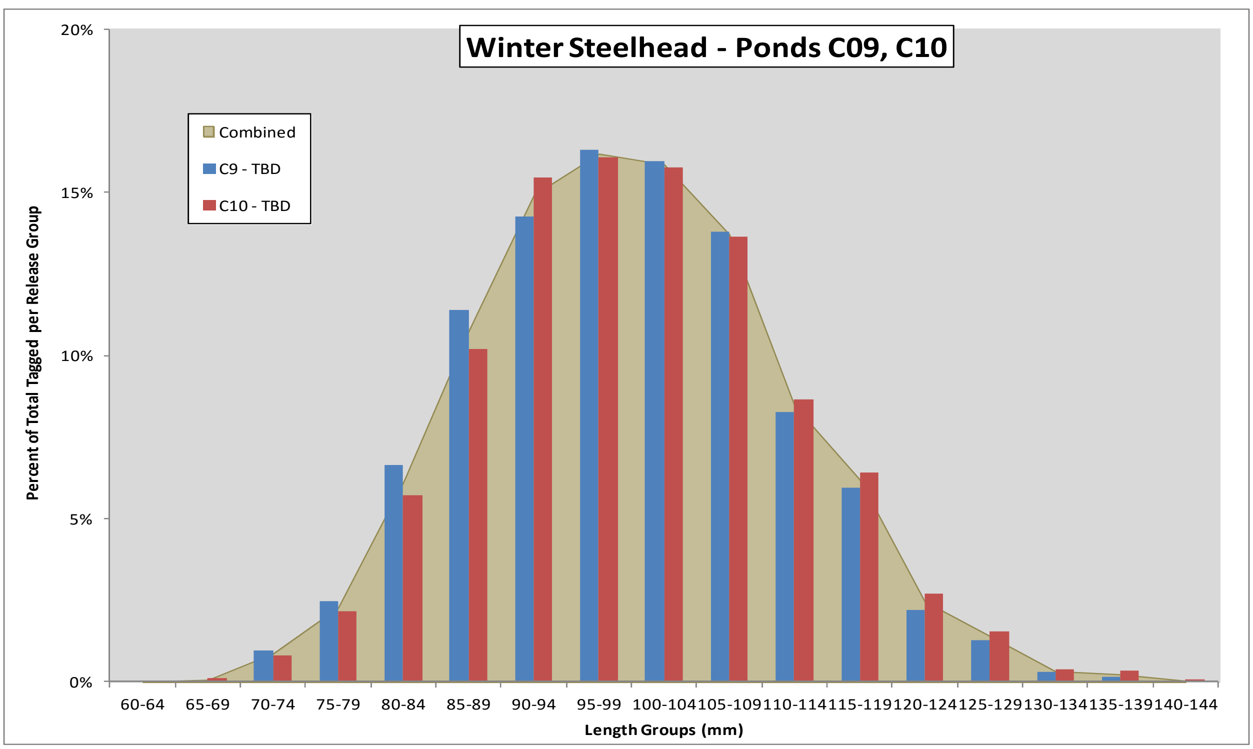

Figure 2. Length frequency of PIT-tagged juvenile winter steelhead tagged for Task 2 at Marion Forks Hatchery, June 2015.

Tables

Table 1. Summary of juvenile subyearling spring Chinook salmon and winter steelhead handled and PIT-tagged for Tasks 1 and 2 at Marion Forks Hatchery, June 2015.

Tag Site	Release Site / River Km	Species	Pond	Number Tagged (A)	Mortality and Shed Tags: During Tagging # (B)	During Tagging # (C)	After Tagging (D)	Total Mort/ Shed Tags (E) = (B+D)	Tagged Fish Available for Release (A-D)	Short (F)	Injured/ Disease (G)	Total Fish Handled (A+F+G)
Marion Forks Hatchery	Dry Creek/ 163.174.019.093	Chinook	C16	33,424	0	0	531	531	32,893	66	102	33,592
	Minto Fish Facility / 163.174.019.067	Chinook	C17	33,379	6	6	525	531	32,854	98	113	33,590
	Dry Creek / 163.174.019.093	Chinook	C18	33,370	17	12	277	294	33,093	72	162	33,604
		Chinook Total		***100,173***	***23***	***18***	***1,333***	***1,356***	***98,840***	***236***	***377***	***100,786***
	TBD	Steelhead	C09	9,231	0	0	10	10	9,221	38	36	9,305
	TBD	Steelhead	C10	9,260	0	0	0	0	9,260	54	61	9,375
		Steelhead Total		***18,491***	***0***	***0***	***10***	***10***	***18,481***	***92***	***97***	***18,680***
Total for Marion Forks Hatchery				**118,664**	**23**	**18**	**1,343**	**1,366**	**117,321**	**328**	**474**	**119,466**

Table 2. Length Summary for juvenile subyearling spring Chinook salmon PIT-tagged for Task 1 at Marion Forks Hatchery, June 2015.

Lengths (mm)							
Pond	Length Count	Average	Median	Mode	Max	Min	% Lengths Recorded
C16	33,310	79.8	80	76	104	61	99.7%
C17	33,279	80.9	81	84	104	62	99.7%
C18	33,266	82.6	83	84	116	61	99.7%
Combined	99,855	81.1	81	84	116	61	99.7%

Table 3. Length Summary for juvenile winter steelhead PIT-tagged for Task 2 at Marion Forks Hatchery, June 2015.

Lengths (mm)							
Pond	Length Count	Average	Median	Mode	Max	Min	% Lengths Recorded
C09	7,991	99.1	99	104	156	64	86.6%
C10	9,235	99.9	99	94	158	64	99.7%
Combined	17,226	99.5	99	94	158	64	93.2%

Appendix A

Table A.1. List of tagging files submitted to PTAGIS for Task 1.

File Name
CSM15176.A18
CSM15176.B18
CSM15176.C18
CSM15176.D18
CSM15178.A17
CSM15178.B17
CSM15178.C17
CSM15178.D17
CSM15179.A16
CSM15179.B16
CSM15179.C16
CSM15179.D16

Table A.2. List of tagging files submitted to PTAGIS for Task 2.

File Name
CSM15175.A09
CSM15175.A10