# Passage Evaluation of Spring Creek Hatchery Subyearling Chinook Salmon at Bonneville Dam Second Powerhouse, 2015

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# Executive Summary


We conducted a biological evaluation to determine the efficacy of a prototype gatewell flow-control device in reducing bypass system mortality for Spring Creek fall Chinook salmon *Oncorhynchus tshawytscha*. At the Bonneville Dam Second Powerhouse, smolt monitoring observations in 2007 and tests in 2008-2009 had confirmed higher rates of bypass-system mortality for these fish during turbine operation at the upper end of the 1% peak efficiency range.

To evaluate potential causes for this increased mortality, gatewell flow patterns were investigated using computational fluid dynamics modeling in 2010-2011. Results from modeling indicated that gatewell hydraulics could be improved by filling the vertical spaces above both sides of a submersible traveling screen (STS) with turbulence reduction devices. These devices were tested in 2013, but did not provide the desired results.

In 2013 and 2014, further investigation of gatewell flows was conducted by the U.S. Army Corps of Engineers. Results from these investigations suggested that flow-control plates positioned on the downstream side of the support beam for the vertical barrier screen (VBS), in combination with modified VBSs, may improve gatewell flow conditions. This report details results from biological tests of these modifications to improve fish survival at the upper end of the 1% efficiency range.

Our study design called for two separate evaluations of the modified test unit, with both evaluations testing operation at the upper end of the 1% peak efficiency range in Turbine Unit 15. We released paired replicate groups of Spring Creek subyearling Chinook salmon for two test series under the following conditions:

Test series 1) Turbine intake slot 15A: both flow-control devices at upper 1% operation
Turbine intake slot 14A: no flow-control devices at middle 1% operation

Test series 2) Turbine intake slot 15C: modified VBS only at upper 1% operation
Turbine intake slot 14A: no flow-control devices at middle 1% operation

Specified flows for testing were 14.2-14.7 kcfs for middle 1% operation in Turbine Unit 14 and 18.0-18.5 kcfs for upper 1% operation in Turbine Unit 15. During all tests, flow and configuration at Turbine Unit 14 were maintained within the standard operating conditions at Bonneville Second Powerhouse. Our study design called for a test with sufficient statistical power to detect a 3% difference in additive mortality between treatment groups, with $\alpha = 0.05$ and $\beta = 0.20$.

Subyearling Chinook salmon were obtained from Spring Creek National Fish Hatchery and PIT-tagged in lots of 100-240 individuals for daily release groups. All releases were made through a hose into the turbine unit intakes slots.

For test series 1 we released 13 paired replicate groups between 1 April and 7 May 2015, for a total of 3,250 fish released. These fish averaged 70 mm fork length over the course of the releases, increasing from 65 mm for the first releases to 75 mm for the last releases. Average weight for all releases was 3.6 g and ranged 2.7-4.8 g.

For test series 2, we released a total of 3,137 fish in 12 paired replicates between 12 and 29 May. Average overall fork length was 79 mm and ranged 77-81 mm from the first to last replicates. Average weight was 5.2 g and ranged 4.3-6.4 g.

We also released a total of 239 fish in six replicates to the bypass system collection channel adjacent to intake slot 14A. These releases were made to quantify baseline timing, tag loss, and mortality not associated with the gatewell environment. Three releases of baseline fish were made during each of the two test series.

Test fish were recaptured at the downstream end of the juvenile bypass system using the separation-by-code (SbyC) system at the Second Powerhouse Juvenile Fish Monitoring Facility (JMF). After examination for injury and/or mortality, recaptured fish were returned to the river through the bypass system outfall pipe.

During test series 1, we observed a significantly higher proportion of mortalities among fish released to intake slot 14A (20.9%) than among fish released to slot 15A (2.1%; $P < 0.001$). A confounding factor was the number of fish from each release location that were never detected after release. Among non-detected fish, the proportion released to slot 15A (22.5%) was much higher than the proportion released to slot 14A (6.4%; $P = 0.003$). Median travel time from release to first detection was also significantly longer for fish released to slot 14A (0.299 d) than for those released to slot 15A (0.183 d; $P = 0.021$).

During test series 2, there was a small but significant difference between the proportion of mortalities observed from releases to slot 15C vs. releases to slot 14A (0.6 vs. 2.1% respectively; $P = 0.029$). There was a slightly larger proportion of non-detected fish from releases to slot 15C (5.0%) than from releases to slot 14A (2.3%), but the difference was not significant ($P = 0.102$). No difference in median travel time was observed between releases to slot 15C (0.470 d) and those released to slot 14A (0.430 d; $P = 0.402$).

We recaptured 95% of fish released to the bypass system collection channel to evaluate baseline passage metrics. No mortality was observed for baseline fish during either test series. Unlike the test fish that were never detected after release, the 5% of baseline fish that were not recaptured had been detected on the full-flow JMF detectors and thus had not been diverted by the separation-by-code system. Median travel time for releases during both test series was 43 minutes.

Observations in 2007 by smolt monitoring personnel and tests conducted by NOAA Fisheries starting in 2008 indicated that tule stock subyearling Chinook salmon were more susceptible to gatewell injury and mortality than other salmonid stocks during periods when turbine units are operated at the upper end of 1% peak efficiency range.

Therefore, extrapolating these test results to other salmonids should be done with caution, because while many stocks of juvenile salmon pass Bonneville Dam, our study fish consisted of only Spring Creek National Fish Hatchery subyearling Chinook salmon. Furthermore, study fish were released at a single location within the intake. Consequently, these results may not be representative of other migrating salmonid stocks or of fish that enter turbine intakes at other locations.

# Contents

# Introduction

Fall Chinook salmon reared at Spring Creek National Fish Hatchery (NFH) are an indicator stock for the Pacific Salmon Treaty between the U.S. and Canada and are also included in treaty obligations to Native Americans. These fish provide mitigation for habitat loss and contribute to sport and commercial fisheries in both rivers and the Pacific Ocean (USFWS 2014). The objective of this study was to determine efficacy of prototype gatewell flow-control devices in reducing bypass-system passage mortality for these fish. On a broader scale, the work represented a step toward the continuing goal of improving passage conditions for juvenile migrants at the Bonneville Dam Second Powerhouse.

In 2007, data and observations from the *Smolt Monitoring Program* (FPC 2008) indicated substantial mortality for Spring Creek fall Chinook salmon during Second Powerhouse turbine operations at the upper end of the 1% peak efficiency range. In 2008 and 2009, biological evaluations confirmed these observations (Gilbreath et al. 2012). Results from these evaluations showed that gatewell passage mortality increased as turbines were operated at higher levels within the 1% peak efficiency range.

These increases in observed mortality were typically associated with lower recapture rates, and longer passage times. In 2008, partial failure of the horizontal seals between vertical barrier screen (VBS) sections resulted in dramatically lowered recapture rates on two occasions. These incidents highlighted the importance of seal integrity in maintaining gatewell containment.

Following biological evaluations in 2008-2009, flow conditions in the gatewell environment were evaluated by USACE using computational fluid dynamics modeling. Modeling results showed that gatewell flow conditions were less than optimum, with notable increases in turbulence at flows representative of the upper end of the 1% peak efficiency range (USACE 2013). Modeling results also indicated that a turbulence reduction device (TRD) could potentially be used to streamline gatewell flow patterns and thus improve passage survival. In 2013, TRDs were installed and biologically evaluated, but they did not provide the desired increase in survival of tested fish stocks (Gilbreath et al. 2014).

After further modeling and collections of physical gatewell velocity data through 2014, a new approach was suggested. This was based on additional hydraulic data showing different flow characteristics between the A, B, and C gatewells, primarily due to scroll case geometry. This new approach used a combination of flow-control plates and modified VBSs to improve the gatewell flow environment during operation at the upper end of 1% peak efficiency.  In 2014, proof-of-concept testing was completed, with results indicating hydraulic improvement (HCE and ARL 2014).

In February 2015, the "A" slot of Turbine Unit 15 was modified with flow-control plates installed at the VBS support beam (at +31 msl).  These modifications blocked 50% of the return flow area between the beam and hydraulic head gate.  The "B" slot of Turbine Unit 15 was modified with flow-control plates that blocked 25% of the return flow area.  The "C" slot was not modified with flow-control plates; however, the porosity of the two uppermost sections of the VBS panels was decreased to the same extent in all three slots of Turbine Unit 15 to address excessive through-screen velocities that had been measured on the VBSs (HCE and ARL 2015).

For biological tests in 2015, we again used subyearling tule stock Chinook salmon obtained directly from Spring Creek NFH.  Tests were conducted from 1 April through 7 May for test series 1 and from 12 to 29 May for test series 2.

# Methods

We compared post-recapture mortality among paired treatment groups of PIT-tagged subyearling Chinook salmon released under turbine operational settings in the middle vs. upper ranges of 1% peak efficiency. Representative flows were 14.2-14.7 kcfs for the middle 1% range and 18.0-18.5 kcfs for upper 1% range of turbine operation. For test series 1, we compared groups released to slot 14A, operated at the middle 1% range, with those released to slot 15A, operated at the upper 1% range. For test series 2, we compared groups released to slot 14A, operated at the middle 1% range, with groups released to slot 15C, operated at the upper 1% range. Passage time was also compared between paired groups for each series.

During both test series, we released additional test fish to the bypass system collection channel adjacent to the north orifice of slot 14A. These fish were used to provide baseline mortality and passage time not associated with passage through a turbine intake and gatewell.

Our study design called for statistical power sufficient to detect a difference of 3% in additive mortality between the two groups at $\alpha = 0.05$ and $\beta = 0.20$. Thus, the null and alternate hypotheses for mortality and gatewell residence time were as follows:

***Null hypothesis***: There is no true difference in fish condition (mortality) rates or gatewell residence time between fish groups passing at upper 1% operations with flow-control devices and modified VBSs vs. those passing at middle 1% operation with no flow-control devices and standard VBSs.

***Alternate hypothesis***: True fish condition and/or gatewell residence time differs between fish groups passing at upper 1% operations with flow-control devices and modified VBSs vs. those passing at middle 1% operation with no flow-control device and standard VBSs

Each hypothesis was expressed for fish condition (FC) and gatewell residence time (GRT) comparison as follows:

Test Series 1

$H_0$ $FC_{upper15A} = FC_{mid14A}$
$H_A$ $FC_{upper15A} \neq FC_{mid14A}$
$H_0$ $GRT_{upper15A} = GRT_{mid14A}$
$H_A$ $GRT_{upper15A} \neq GRT_{mid14A}$

Test Series 2

$H_0$ $FC_{upper15C} = FC_{mid14A}$
$H_A$ $FC_{upper15C} \neq FC_{mid14A}$
$H_0$ $GRT_{upper15C} = GRT_{mid14A}$;
$H_A$ $GRT_{upper15C} \neq GRT_{mid14A}$

We calculated treatment group sizes necessary to detect an additive difference, *d*, given a background or control effect, $p_1$, with $\alpha = 0.05$ and $\beta = 0.20$ by using the following equation from Zar 1999:

$$n \approx \frac{(t_{\alpha/2} + t_{\beta})^2 [p_1(1-p_1) + (p_1 + d)(1-p_1-d)]}{d^2} \approx \frac{8[p_1(1-p_1) + (p_1+d)(1-p_1-d)]}{d^2}$$

where *d* is the specified additive difference, $p_1$ is the expected background or control effect, and $t_{\alpha/2}$ and $t_{\beta}$ are the *t*-values corresponding to $\alpha = 0.05$ and $\beta = 0.20$. We estimated $p_1$, the expected lower 1% mortality rate at 0.03 (3%), based on results from our studies of 2008-2009 and 2013. The additive difference between the upper 1% vs. the middle 1% treatment, *d*, was specified as 3%. Individual test releases are detailed in Appendix Table 1, and operational conditions are shown in Appendix Table 2.

Test fish were collected by grab sample from Spring Creek NFH ponds, weighed to estimate number, and then transported to the Second Powerhouse juvenile fish monitoring facility in 75-L oxygenated containers. Duration of transport was about 45 min. At the Bonneville Dam juvenile monitoring facility (JMF), fish were transferred water-to-water into 720-L rectangular tanks supplied with flow-through river water. Fish were held undisturbed for 16-24 h for temperature acclimation and stress reduction before tagging. Water temperatures in the Columbia River ranged 9.3-13.4°C during test series 1 and 14.0-16.9°C during test series 2.

Prior to tagging, fish were anesthetized using tricaine methane sulfonate (Argent Labs, Redmond, Washington)[1] at a concentration of about 50 mg/L. We used 134.2-kHz FDXB ISO PIT tags (12.5 mm long by 2.0 mm diameter). Tags were preloaded into single-use needles and injected with an MK-25 rapid-implant gun (Biomark Inc., Boise, Idaho). Successful implantation was confirmed by scanning tag codes into a computer file using P3 tagging software developed by the Pacific States Marine Fisheries Commission (PSMFC 2015). We also recorded weight in grams and fork length in millimeters for each fish tagged.

Tagged fish were placed into 75-L containers and held overnight for release the following day. On the morning of release, holding containers were checked for shed tags and mortalities. Live study fish were transferred into divided 720-L truck-mounted tanks for releases into turbine intakes. Fish for baseline evaluation were placed in a 720-L tank in the bypass system collection channel gallery for release into the collection channel adjacent to the north orifice of intake slot 14A.

[1] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Fish were released through a 10.2-cm-diameter PVC hose to a point about 3 ft below the intake ceiling and about 5-6 ft behind the trash rack (Figure 1). The release-hose support mechanism was identical to that used in our studies in both 2008-2009 and 2013 (Gilbreath et al. 2012, 2014). We duplicated this PVC hose and release-hose support mechanism for the second release hose needed for this study.

Figure 1 shows a side view of the turbine with approximate release locations and gatewell structures relevant to the study. To recapture study fish, we programmed their tag codes for diversion by the separation-by-code (SbyC) system at the JMF. Figure 2A shows a plan view of Bonneville Dam Second Powerhouse, and Figure 2B shows locations of the SbyC system and PIT-tag monitors within the monitoring facility.

Recaptured test fish and bycatch were scanned for presence of tags, and data were entered into P3 files for upload to the PTAGIS database. Tagging and recapture file data were later imported into spreadsheet and relational database programs for summary and analysis. We used individual daily paired release cohorts as replicates. Statistical significance was determined using a paired *t*-test.

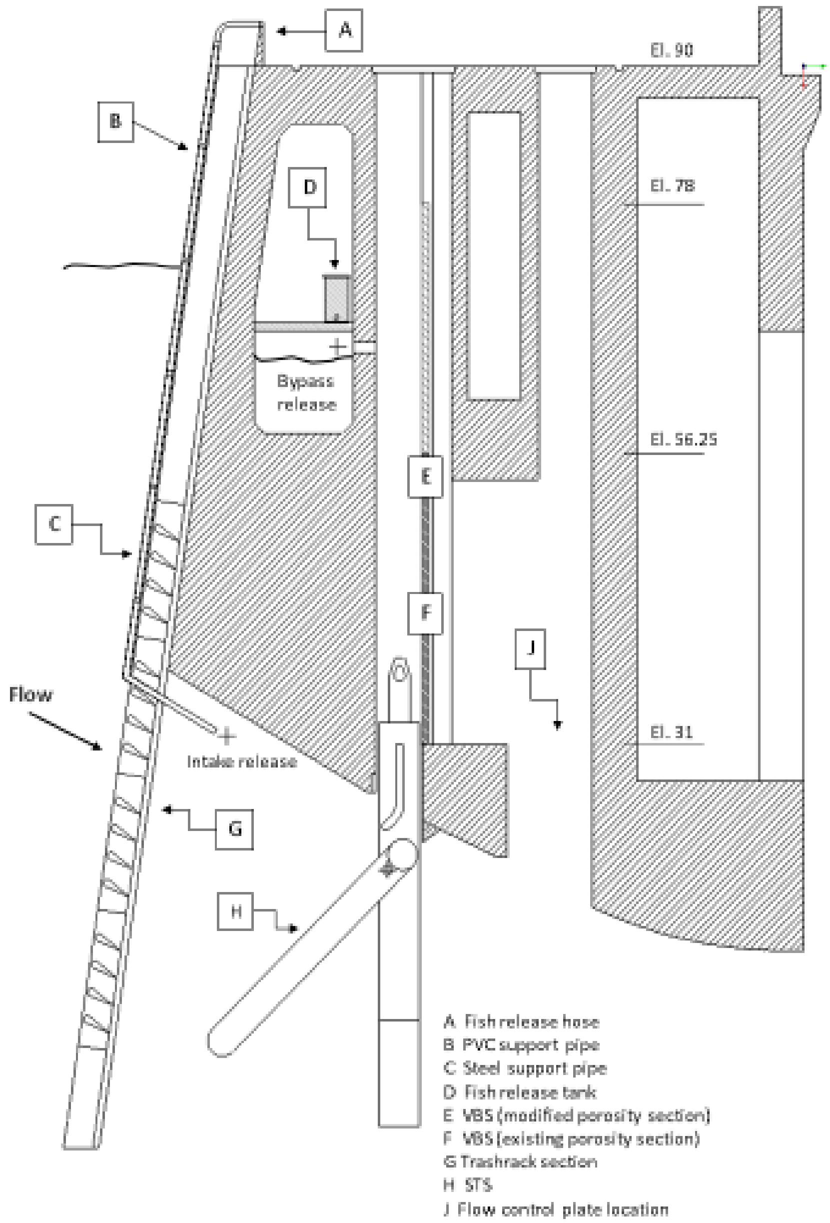


Figure 1. Partial transverse section through a turbine intake and gatewell at Bonneville Dam Second Powerhouse. Standard fish guidance structures and release locations used in 2015 are labeled. Elevations are in ft msl. Crosshair symbols denote release locations. Abbreviations: VBS, vertical barrier screen; STS, submersible traveling screen.

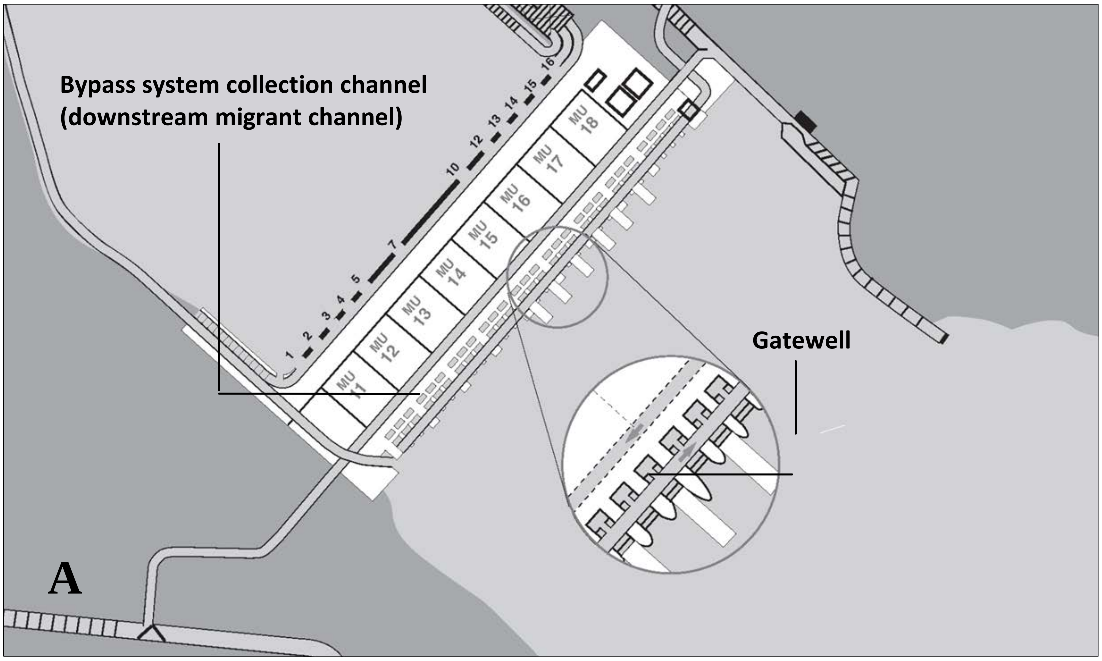


Figure courtesy U.S. Army Corps of Engineers

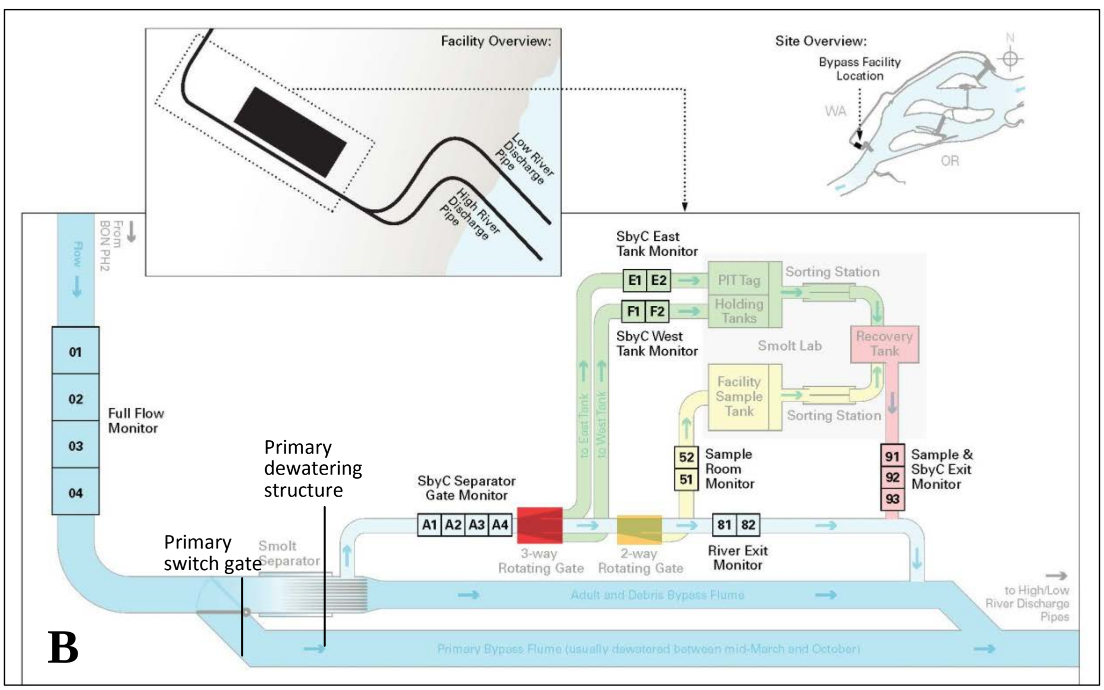


Figure courtesy of Pacific States Marine Fisheries Commission

Figure 2. Upper panel (A) shows plan view of Bonneville Dam Second Powerhouse with locations of turbine unit gatewells and collection channel. Lower panel (B) shows plan view of the Juvenile Fish Monitoring Facility with location of full flow monitor, primary switch gate, and SbyC monitors.

# Results

Biological tests were scheduled to be completed within a specified time to avoid periods of heavy passage by Spring Creek NFH production releases. This schedule helped to minimize exposure of production fish to the upper 1% turbine operating condition and also helped to avoid excessive numbers of bycatch and tag collision (wherein two tags are detected and emit codes simultaneously such that neither tag code is read by the transceiver).

As observed during previous studies using fish obtained from Spring Creek NFH, fish in 2015 showed no indication of condition problems during pre-release handling. The duration of handling procedures was about 48 h from acquisition at the hatchery to release. For most fish, this handling period approximated the time that would otherwise have been spent migrating in the river between release at Spring Creek NFH and arrival at Bonneville Dam. Acclimation to river temperature was not required due to similar temperatures between the hatchery and release sites.

Of the 6,626 fish tagged during this study, we observed no tag loss and only four mortalities. Of live fish recaptured, none were noted as either descaled or partially descaled based on the criteria of Ceballos et al. (1993). One recaptured fish was noted as having operculum damage that had not been recorded at the time of tagging.

Results in this section are reported in the following sequence for each test series.

1) Detection and recapture outcomes observed in the study
2) Observed mortality rates based on fish recaptured with tags in situ—the primary measure of results
3) Passage timing from release to first detection in the bypass system
4) Recovery of tags last detected on the full-flow monitors, including bare tags from the bypass system after the system was dewatered[2]

[2] We used the term “bare tag” to denote a tag which likely dropped from a fish post-mortem as opposed to tags lost or shed from live fish.

## Test Series 1

Test series 1 compared fish released during upper 1% turbine operation with flow-control plates and a modified VBS (slot 15A) to fish released during middle 1% turbine operation with standard gatewell conditions (slot 14A). The prototype flow-control plates in slot 15A blocked 50% of the return flow area.

A total of 3,250 tule subyearling Chinook salmon were released for this evaluation (Appendix Table 1). Test fish ranged 52-103 mm with an average length of 70 mm. Average length was 65 mm for the first replicates but increased over the test period to 75 mm for the last replicates. Weight for these fish ranged 1.3-11.7 g and averaged 3.6 g. Early replicates weighed an average of 2.7 g while the last replicates averaged 4.8 g.

### Detection and Recapture Outcomes

We identified five outcome categories from releases during test series 1. Study fish in the two primary categories were those recaptured with tags in situ, either alive or dead. After examining study fish detection data downloaded from the PTAGIS database, we identified three additional categories: study fish that were detected, but for which we recovered a tag but no fish, study fish that were detected, but for which we recovered neither a tag nor a fish, and study fish that were never detected after release.

Detection and recapture outcome categories for each treatment group are shown in Figure 3. Percentages in each category were based on overall counts rather than averages of replicates. About 86% of fish released at the middle 1% operation into slot 14A were recaptured with tags in situ. The recapture rate dropped to about 75% for upper 1% releases into slot 15A. A similar percentage of fish from each release slot were recaptured alive (73% from slot 14A and 74% from slot 15A).

Records in PTAGIS indicated that a number of tags were last detected on the full-flow detectors just upstream of the JMF. On 23 June, we recovered bare tags from study fish in the area between the juvenile facility primary switch gate and the primary dewatering structure (Figure 2). Comparison of these tag codes with our tagging records showed that these tags represented 3% of the fish released into slot 14A and less than 1% of the fish released into slot 15A.

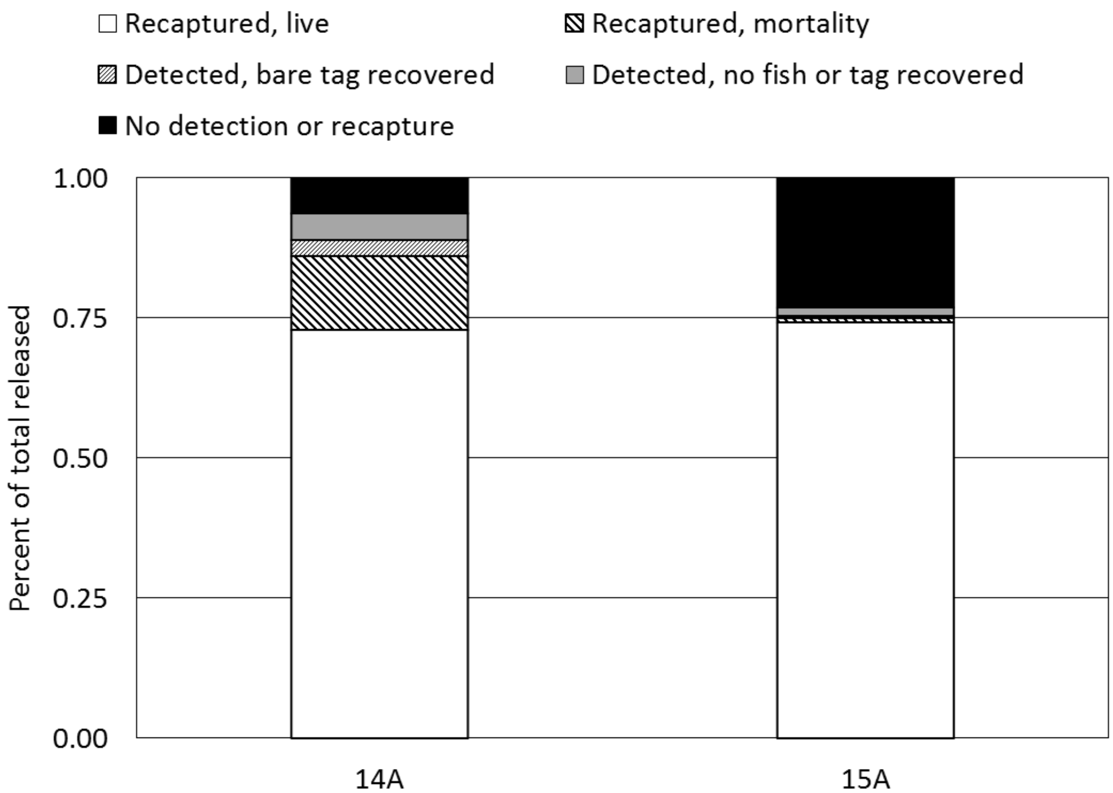


Figure 3. Proportions of fish in each of five recapture and detection outcome categories for test series 1 treatment groups. Study fish were subyearling Chinook salmon released to the 14A and 15A turbine intake slots at Bonneville Dam Second Powerhouse, 2015.

Only 2-5% of fish from each treatment group fell into the category of detections for which neither a fish nor a tag was recovered. Some fish in this category were missed by the SbyC rotational gate, likely due to tag collisions from high numbers of PIT-tagged fish present in the system. Others may have been bare tags that we did not recover from the holding raceway or from the flume between the head wall and primary dewatering structure.

Percentages of tagged fish not accounted for by recapture, tag recovery, or detection were significantly different between the two release conditions. Fish that were never detected after release comprised about 6% of the total released to slot 14A (middle 1% operation) and about 23% of the total released to slot 15A (upper 1% operation; $t = 3.6$, $P = 0.003$). Fish in this category may have passed through the gap at the top of the submersible traveling screen, passed under the traveling screen, escaped gatewell containment by some other means, or may represent unrecovered mortalities.

We also checked the PTAGIS database for detections of test fish at other downstream locations. One fish was detected on the Bonneville Second Powerhouse corner collector. This fish had been released to slot 14A but was not detected for 9 d after release. During test series 1, a total of six fish were detected on the pile dike detectors in the estuary (three from 14A, three from 15A; PTAGIS site code PD7). Another six fish were detected at the estuary pair trawl (four from 14A, two from 15A; PTAGIS site code TWX). All twelve had been detected in the juvenile bypass system.

We obtained preliminary information on PIT tags deposited on East Sand Island avian colonies (Allen Evans, Real Time Research personnal communication). A total of 181 PIT tags released for test series 1 were detected on the island. Of these 181 tags, 78 (out of 1,621 released) were from fish released to slot 14A, and 103 (out of 1,629 released) were from fish released to slot 15A.

Of the 78 tags found on avian colonies from fish released to slot 14A, all were from fish that had been observed on full flow detectors at the juvenile fish facility (100%). Thus no tags from never-detected fish were found on the island.

Of the 103 fish from releases to slot 15A with tags found on avian colonies, 90 (87%) had been detected on full flow detectors and 13 had never been detected after release. Those 13 fish represented 3.2% of all fish never detected after release. These data suggest that a large proportion of never-detected fish released to slot 15A likely survived to the estuary.

## Observed Mortality at Recapture

Table 1 summarizes total numbers released in each group, as well as average recapture and observed mortality rates. As expected, baseline releases into the collection channel had the highest recapture rate (98.2%) and lowest mortality rate (0.0%). Releases to slot 14A represented the standard by which the effectiveness of gatewell-passage improvement was to be assessed.

This standard was based on results from FGE testing conducted in 2008 and 2009 as well as on regional coordination for acceptable interim turbine operations for river-run bypassed fish. This standard limits unit operation to not exceed the middle 1% peak efficiency, or not to exceed a maximum allowable unit flow of approximately 15 kcfs. Releases into slot 14A had a recapture rate of 89.6% and an observed mortality rate of 18.8%. In comparison, test fish released into slot 15A at the upper 1% of the peak efficiency range had a recapture rate of 75.9% and an observed mortality rate of 1.6%.

Table 1. Mean observed mortality rates for subyearling Chinook released to intake slots 15A and 14A at Bonneville Dam Second Powerhouse, 1 April-7 May 2015. Turbine unit flows were relative to the 1% peak efficiency range.

| Release location | Turbine operation | Turbine unit flow (kcfs) | Released (n) | Recaptured (%) | Mortality (%) |
|---|---|---|---|---|---|
| Intake slot 15A | upper 1% | 18.0-18.5 | 1,629 | 75.9 | 1.6 |
| Intake slot 14A | middle 1% | 14.0-14.5 | 1,621 | 89.6 | 18.8 |
| Collection channel | n/a | | 109 | 98.2 | 0.0 |

## Bypass System Passage Timing

Figure 4 shows median passage time from release to initial detection at the full flow detectors for releases in test series 1. Fish were released to the bypass system collection channel (also called downstream migrant channel, or DSM) for baseline passage metrics. Paired treatment groups were released to turbine intake slots 15A (upper 1% operation) and 14A (middle 1% operation). Passage mortalities were excluded from all analyses of timing data.

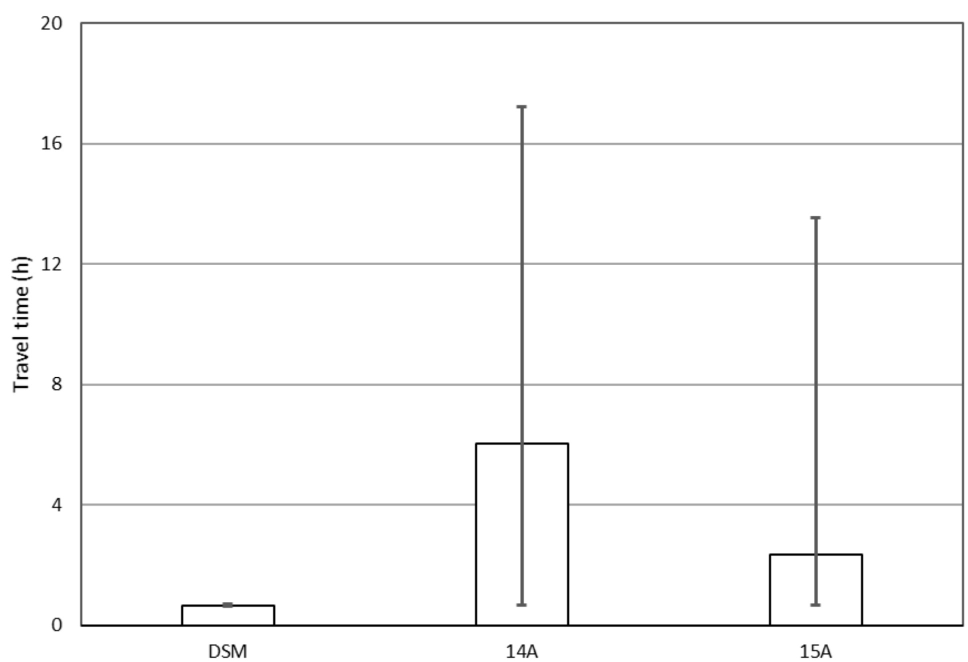


Figure 4. Median time to detection at the full flow detectors in the juvenile fish facility for hatchery subyearling Chinook salmon released to the collection channel or turbine intake at Bonneville Dam Second Powerhouse in 2015. Whisker bars denote 10th and 90th passage percentiles.

Test fish released to slot 15A (upper 1% operation) were observed at the JMF within 37 minutes after release. For these fish, median passage time was 2.4 h, and the $10^{th}$ and $90^{th}$ passage time percentiles were 40 minutes and 13.6 h, respectively. Passage time for these fish was significantly faster than passage timing of fish released to slot 14A, based on analysis of paired replicates ($t$ = 2.66, $P$ = 0.021). The slowest passage time was 35.9 d. Median passage time for fish later found to be mortalities was slower than that of live fish by about 36 minutes.

Test fish released into slot 14A (middle 1% operation) were also observed at the full flow detectors within 37 minutes after release. Median passage time was 6.0 h, and the $10^{th}$ and $90^{th}$ passage time percentiles were 39 minutes and 17.2 h, respectively. The slowest passage time was 64.5 d. Median passage time of fish later found to be mortalities was slower than that of fish recovered alive by about 7.0 h.

Fish released to the collection channel for baseline evaluation had a median passage time of 38 minutes. Overall passage time was tightly grouped for this release, with $10^{th}$ and $90^{th}$ passage percentiles of 37 and 41 minutes, respectively. The shortest passage time for these fish was 35 minutes and the longest was 147 h. Two fish released on 7 May had travel times of just over 147 h. Both were recaptured alive and observed on the full flow detectors within 4 minutes of each other. The longest travel time, excluding these two fish, was 55 minutes.

We calculated hourly passage during the 3 d after release as a percentage of the total number of fish released in each group. This allowed direct comparison of passage timing distributions among treatment groups (Figure 5). Examination of these distributions showed that for both groups, the highest percentage of fish passed during the first hour after release. Of fish released to slot 15A (upper 1% operation), 23% passed during the first hour, and of fish released to slot 14A (middle 1% operation), 27% passed during the first hour after release.

Passage during the second hour declined to less than 7% for fish released to slot 14A (middle 1% operation) and to 12% or less for fish released to slot 15A (upper 1% operation). Minimal passage occurred from the fourth through the eleventh hour after release. A typical evening peak in passage activity was observed, with higher rates of passage for both release groups during the twelfth to fourteenth hour after release. For both groups, passage proportions again dropped to low levels between the fourteenth and twenty-fourth hour after release. Passage rates following the 24th hour were relatively higher for fish released to slot 14A than for those released to slot 15A; this contributed to a significantly longer median gatewell residence time for 14A releases.

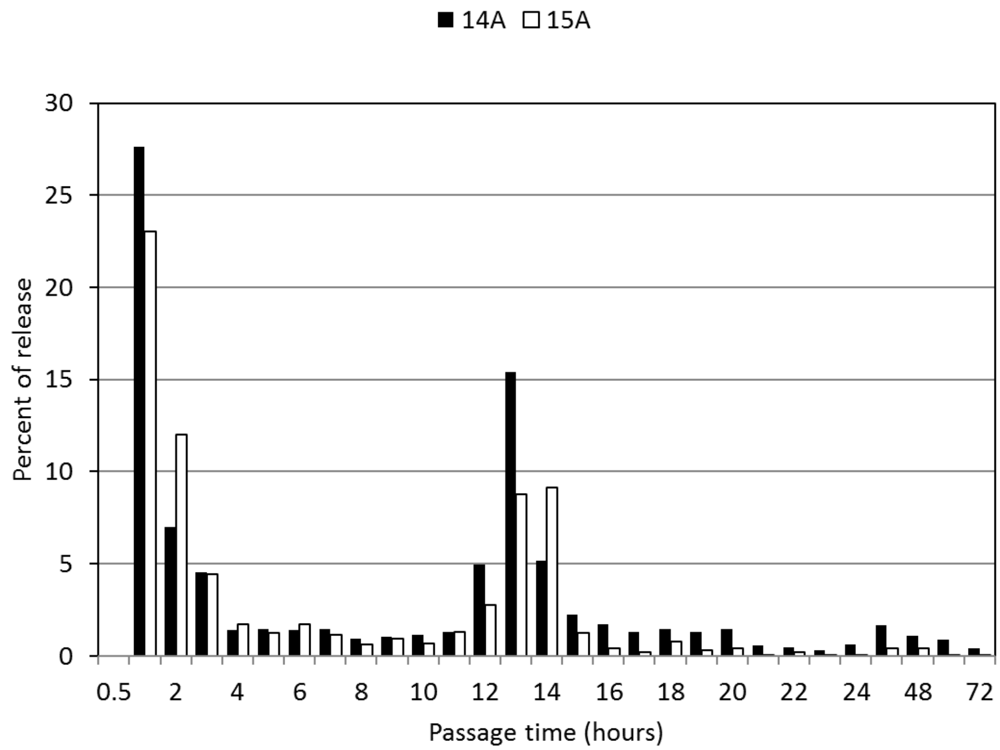


Figure 5. Passage timing distribution for PIT-tagged hatchery subyearling Chinook salmon released at Bonneville Dam Second Powerhouse, from time of release to time of first detection at the juvenile fish facility, test series 1, 2015.

## Recovery of Tags Last Detected at the Full-Flow Detectors

We queried the PTAGIS database to retrieve information on downstream detections of study fish. These data showed that 91 PIT tags from fish released in test series 1 were observed only on the full-flow detectors. This series of detectors are the first encountered by fish passing through the Second Powerhouse JMF (Figure 2B). Overall, observations on only the full-flow detectors accounted for 14.7% of fish not recaptured following release during test series 1. This detection history indicates study fish (including bare tags) were lost either through the primary switch gate, by tag collision at the SbyC gate, or in the dewatering structure (Figure 2B).

Many of these detections matched bare tags recovered from the approach flume of the primary dewatering structure after it was dewatered on 23 June (Table 2). Overall, 56.0% of the tags detected only on the full-flow monitor were found at this location. Tags that were detected but never recovered may have been missed during our recovery effort. Alternatively, they may have collected under the primary switch gate and been flushed down the bypass flume to the river when the gate was moved to bypass position (Figure 2B).

Table 2. Number of PIT tags last detected at the full flow monitor and recoveries of bare tags from the primary dewatering structure approach flume. Study fish were Spring Creek NFH subyearling Chinook salmon released at Bonneville Dam Second Powerhouse in 2015 during test series 1.

| Release groups | Total tagged fish released (n) | Detected only at full flow monitor (n) | Bare tags recovered at primary dewatering structure | |
|---|---|---|---|---|
| | | | n | % |
| Intake slot 15A (upper 1%) | 1,629 | 13 | 4 | 30.8 |
| Intake 14A slot (middle 1%) | 1,621 | 76 | 47 | 61.8 |
| Collection channel | 109 | 2 | 0 | n/a |
| Totals | 3,359 | 91 | 51 | 56.0 |

## Test Series 2

Test series 2 compared releases to intake slot 15C (upper 1% operation) with standard gatewell conditions in slot 14A (middle 1% operation). For these comparisons, the test gatewell (15C) was fitted with a modified VBS, but flow-control plates were not used.

For test series 2, we released a total of 2,898 PIT-tagged subyearling Chinook salmon from Spring Creek NFH. Test fish ranged 57-112 mm with an average fork length of 79 mm. Average length for the first paired replicate was 77 mm, but length increased during the study period to a maximum average of 81 mm for the last paired replicate. Weight of these fish ranged 1.6-15.1 g and averaged 5.2 g. Initial groups averaged 4.3 g while the last replicates averaged 6.4 g (Appendix Table 1).

### Detection and Recapture Outcomes

For fish in test series 2, we used the same five detection and recapture outcome categories identified for fish in test series 1. Study fish in the two primary categories were those recaptured with tags in situ, either alive or dead. Using detection data from the PTAGIS database, we identified three additional categories: detections for which we recovered a tag but no fish, detections for which we recovered neither a tag nor a fish, and study fish that were never detected after release.

Detection and recapture outcome categories for treatment groups are shown in Figure 6. Percentages were based on overall counts per treatment group rather than the averages of individual paired replicates. Recapture rates were similar between release locations. About 90% of fish released to slot 15C (upper 1% operation) were recaptured with tags in situ, compared to about 92% of fish released to slot 14A (middle 1% operation). Observed mortality was low throughout the test series for both release sites, with less than 1% mortality for releases to 15C and 2% mortality for releases to14A.

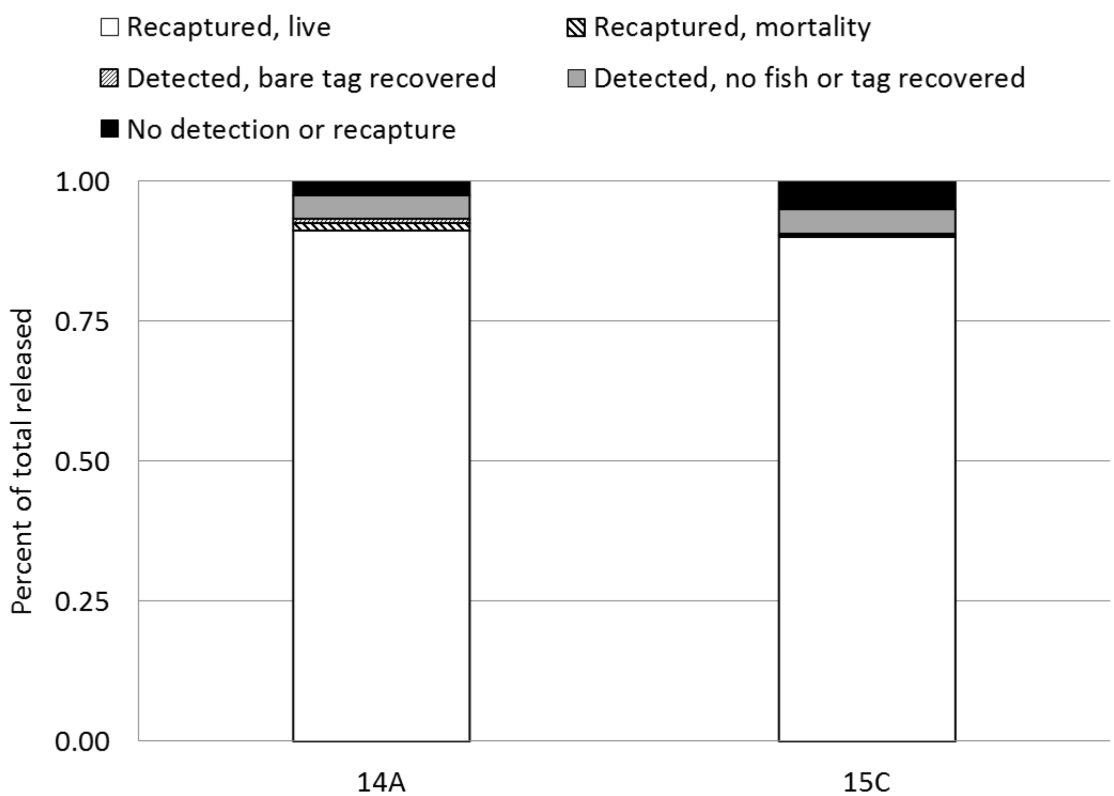


Figure 6. Proportions of fish in each of five potential recapture and detection outcome categories for test series 2 at Bonneville Dam Second Powerhouse, 2015. Treatment groups were subyearling Chinook salmon released into the 14A and 15C turbine intake slots.

Records in PTAGIS indicated that a number of tags were last observed on the full-flow detectors. On 23 June, we recovered bare tags in the area between the primary switch gate and primary dewatering structure (Figure 2B). Comparison of these tag codes with our tagging records showed that these bare tag recoveries represented 0.6% of the fish released to slot 14A and less than 0.1% of the fish released to slot 15C.

Only 4% of fish from each treatment group fell into the category of detections for which no fish or tag was recovered. Some fish in this category were missed by the SbyC rotational gate, likely due to tag collisions from high numbers of PIT-tagged fish present in the system. Others may have been bare tags that we did not recover from the holding raceway or from the flume between the head wall and primary dewatering structure.

In contrast to observations from test series 1, relatively small percentages of tagged fish from either release group in test series 2 were not accounted for by recapture, tag recovery, or detection. About 3% of fish released to slot 14A and about 5% of those released to slot 15C were never detected after release. Fish in this category may have passed through the gap at the top of the submersible traveling screen, passed under the traveling screen, escaped gatewell containment by some other means, or may represent unrecovered mortalities.

We also checked the PTAGIS database for detections of test fish at downstream locations. Of fish released for test series 2, a total of nine were detected on the pile dike detectors in the estuary (four from 15C and five from 14A; PTAGIS site code PD7). Another 18 fish were detected on the estuary pair trawl (ten from 15C and eight from 14A; PTAGIS site code TWX). One fish released into slot 14A was detected at both downstream locations and was counted in both groups above. As was the case in test series 1, all fish detected at these downstream locations had been detected in the juvenile bypass system.

We obtained preliminary information on PIT tags deposited on East Sand Island avian colonies (Allen Evans, Real Time Research, personnal communication). A total of 203 PIT tags from fish released for test series 2 were detected on the island. Of these 203 fish, 99 were from releases to slot 14A (middle 1% operation), and 104 were from releases to slot 15C (upper 1% operation).

Of the 99 fish from releases to slot 14A with tags found on avian colonies, 98 (99%) had been observed on full flow detectors at the juvenile facility, with one fish never detected after release. This fish represented 2.8% of all non-detected fish released to slot 14A during test series 2.

Of the 104 fish from releases to slot 15C with tags found on avian colonies, 101 (97%) had been observed on the full flow detectors and 3 (3%) had not been detected after release. Those 3 fish represent 3.8% of all non-detected fish released to slot 15C. The small proportions of non-detected study fish with tags on avian colonies suggest that a large proportion of non-detected fish survived to the estuary.

## Observed Mortality at Recapture

Table 3 summarizes total numbers of fish released for test series 2, as well as average recapture and observed mortality rates for fish from each treatment group. As expected, the highest rate of recapture (93.1%) was from baseline releases to the collection channel adjacent to the 14A North Orifice. Fish from baseline release groups also had the lowest mortality rate (0.0%).

Table 3. Mean observed mortality rates for recaptured subyearling Chinook salmon released to Turbine intake slots 15C and 14A at Bonneville Dam Second Powerhouse, 12-29 May 2015. Turbine operation is relative to the 1% peak efficiency range.

| Release location | Turbine operation | Turbine unit flow (kcfs) | Released (number) | Recaptured (%) | Mortality (%) |
|---|---|---|---|---|---|
| Intake slot 15C | upper 1% | 18.0-18.5 | 1,471 | 90.6 | 0.5 |
| Intake slot 14A | middle 1% | 14.0-14.5 | 1,427 | 93.5 | 2.0 |
| Collection channel | n/a | | 130 | 93.1 | 0.0 |

Treatment groups released into slot 14A represented the standard by which the effectiveness of gatewell-passage improvement was to be assessed. This standard was based on results from FGE testing conducted in 2008 and 2009 as well as on regional coordination for acceptable interim turbine operations for river run bypassed fish. This standard limits unit operation to not exceed the middle 1% peak efficiency, i.e., maximum allowable unit flow of approximately 15 kcfs. These groups had a recapture rate of 93.5% and an observed mortality rate of 2.0%. Treatment groups released to slot 15C represented test conditions of turbine operation at the upper 1% of the peak efficiency range. These groups had a recapture rate of 90.6% and an observed mortality rate of 0.5%.

## Bypass System Passage Timing

Figure 7 shows median passage time from release to first detection on the full-flow detectors at the Second Powerhouse JMF. Mortalities were excluded from all analyses of passage timing data. Replicate groups of subyearling Chinook salmon were also released to the collection channel (or downstream migrant channel—DSM) for baseline passage metrics.

For test series 2, baseline fish released to the collection channel had a median passage time of 37 minutes. Overall passage time was tightly grouped for baseline releases, with 10th and 90th passage percentiles of 36 and 41 minutes, respectively. The most rapid passage time for baseline fish was 35 minutes and the slowest was 48 h.

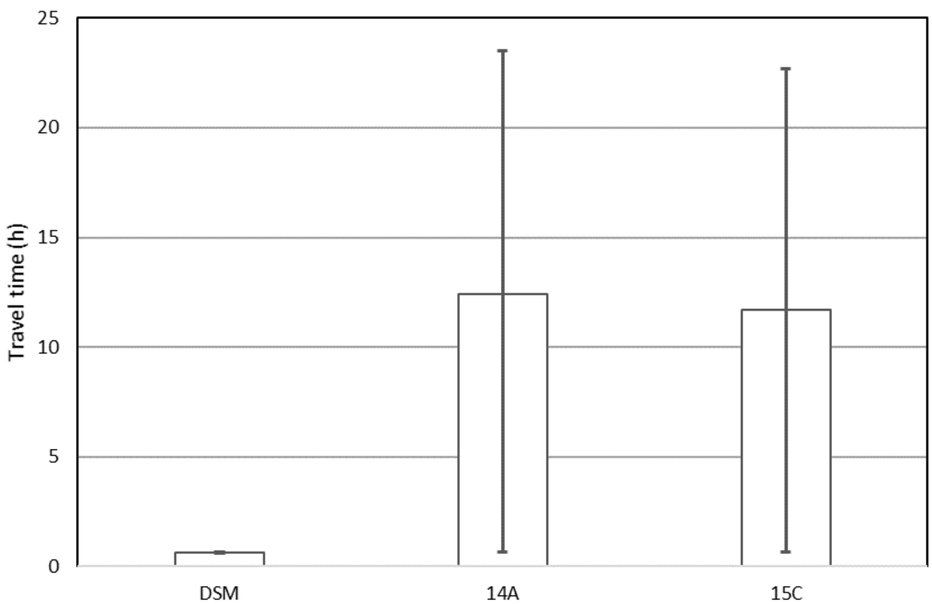


Figure 7. Median time to detection at the full flow detectors in the juvenile fish monitoring facility for hatchery subyearling Chinook salmon released to the collection channel or turbine intakes at Bonneville Dam Second Powerhouse in 2015. Whisker bars denote 10th and 90th passage percentiles.

Test fish released into slot 14A (middle 1% operation) were observed at the JMF within 36 minutes after release. Median passage time was 12.4 h, and the 10th and 90th passage time percentiles were 39 minutes and 23.7 h, respectively. The slowest passage time was 16.9 d. While mortalities were excluded from the data used to estimate passage time, median passage time for mortalities was slower that of fish recaptured alive by about 2.3 h.

Test fish released into slot 15C (upper 1% operation) were also observed at the JMF within 36 minutes after release. For these fish, median passage time was 11.7 h, and 10th and 90th passage time percentiles were 39 minutes and 22.7 h, respectively. Although median passage time for fish released to slot 15C was slightly shorter than for fish released to slot 14A, the difference was not significant ($t$ = 0.87, $P$ = 0.40). The slowest passage time for slot 15C releases was 12.6 d. Median passage time of fish later found to be mortalities was only about 30 minutes slower than that of fish recaptured alive.

We calculated hourly passage during the 3 d after release as a percentage of the total number of fish released in each group. This allowed direct comparisons of timing distribution among treatment groups (Figure 8).

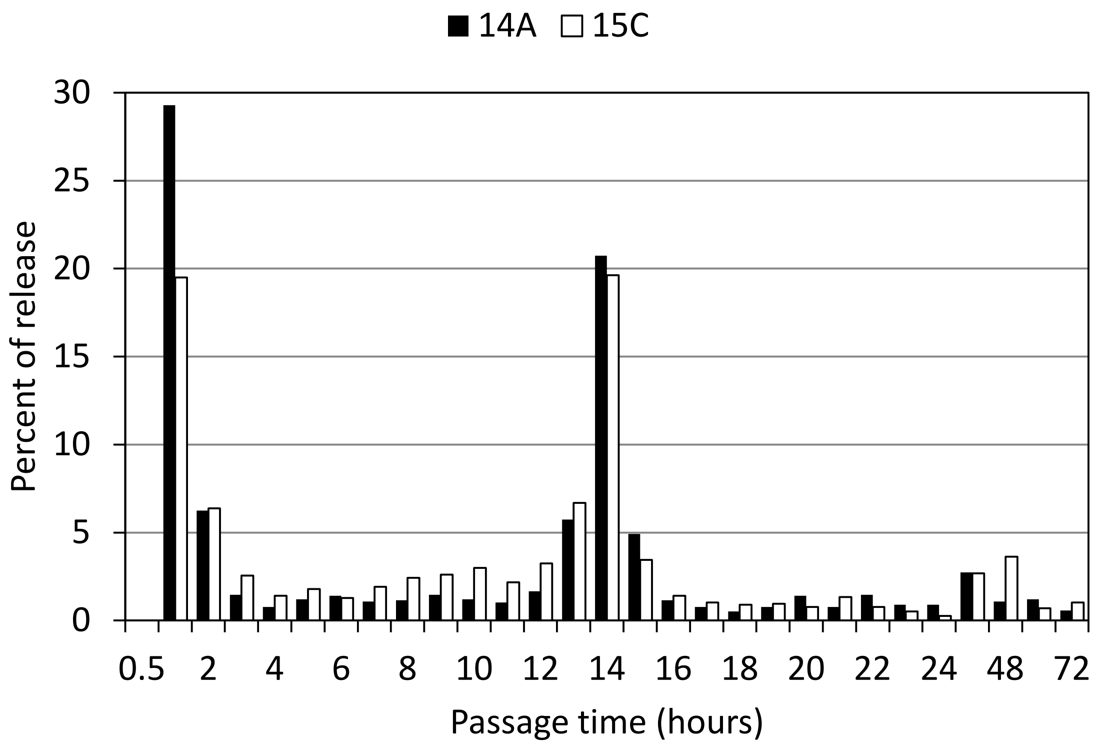


Figure 8. Passage timing distribution for PIT-tagged hatchery subyearling Chinook salmon released at Bonneville Dam Second Powerhouse, from time of release to first detection at the juvenile fish facility, test series 2, 2015

Examination of passage-time distributions showed that for both groups, the highest percentage of fish passed during the first hour after release: 29% of the fish released to slot 14A (middle 1% operation), and ~20% of the fish released to slot 15 C (upper 1% operation). For both turbine release groups, passage proportions declined to just over 6% during the second hour after release, and minimal proportions of fish passed between the third and twelfth hour. Both groups also exhibited the typical evening peak in passage during the thirteenth and fourteenth hour after release.

Thereafter, passage again dropped to low levels for both groups through the 24th hour after passage. An upward trend or "tail," or increase in passage during the later post-release hours, was observed for both treatment groups in this test series. This "tail" in the passage-time distributions of both groups contributed to their similar median gatewell passage time. We attribute this longer gatewell residence primarily to the longer daylight period during test series 2. The evening peak in passage occurred roughly 1 h later for fish released during test series 2 than for those released during test series 1.

## Recovery of Tags Last Detected at the Full Flow Detectors

We queried the PTAGIS database to retrieve information on downstream detections of study fish subsequent to our study. These data showed that 130 fish from test series 2 releases had been observed only on the full-flow detectors. Overall, fish detected only on the full-flow monitors accounted for 55.3% of fish not recaptured following release. This detection history indicated a loss of test fish between the full-flow monitors and primary switch gate or between the full-flow monitors and primary dewatering structure (Figure 2B).

After the smolt separator was dewatered, we recovered a few bare tags in the approach flume of the primary dewatering structure; all of these tags had been detected only on the full-flow monitors (Table 4). Overall, tags found at this location comprised 8.5% of the total number of tags from fish detected only on full-flow monitors. This proportion was far lower than the 56.0% of such tags found in the approach flume from fish released during test series 1.

Table 4. Number of PIT tags last detected at the full flow monitor and recoveries of bare tags from the approach flume of the primary dewatering structure (Figure 2B). Study fish were Spring Creek NFH subyearling Chinook salmon released at Bonneville Dam Second Powerhouse in 2015 during the second test series.

| Release groups | Total tagged fish released (n) | Detected only at full flow monitor (n) | Bare tag recovered at primary dewatering structure | |
|---|---|---|---|---|
| | | | n | % |
| Intake 15C (upper 1%) | 1,471 | 62 | 2 | 3.2 |
| Intake 14A (middle 1%) | 1,427 | 60 | 9 | 15.0 |
| Collection channel | 130 | 8 | 0 | n/a |
| Totals | 3,028 | 130 | 11 | 8.5 |

Tags that had been detected only on the full-flow monitors but not recovered may have been missed during this recovery effort. They may alternately have been flushed down the bypass flume to the river after the primary switch gate was moved to bypass position (Figure 2B).

These areas were not dewatered for clean-out until about 3 weeks after completion of test series 2 and about 6 weeks after completion test series 1. The additional time prior to dewatering may have facilitated the accumulation of bare tags from test series 1, and this may offer a possible explanation for the higher proportion of bare tags found from test series 1.

# Discussion

This study was undertaken to evaluate modifications to improve bypass-system passage survival for tule stock subyearling Chinook salmon from Spring Creek NFH. In 2013, we evaluated turbulence reduction devices (TRDs) designed for this same objective. The results at the upper 1% with the TRD in vs. TRD out indicated that the TRD concept was not a viable standalone alternative. We did determine that turbine operation at the lower 1% allowed fish to survive in the gatewell for extended periods of time. Most previous studies had indicated that longer gatewell residence time resulted in lower survival. (Gilbreath et al. 2012, 2014).

Similar observations resulted from previous biological evaluations conducted during 2008-2009 using Spring Creek NFH stock. These studies compared flows among the lower, lower-middle, middle, upper-middle, and upper ranges within the 1% peak efficiency range. Flows tested ranged from 11.7 to 17.8 kcfs (Gilbreath et al. 2012). In fish from these tests, recapture rates were lower and mortality rates higher for releases to turbine units operating at the middle 1% of the peak efficiency range (14.7 kcfs) than for releases to units operating at the lower-middle 1% (13.5 kcfs; Gilbreath et al. 2012).

Similar relationships were noted for run-of-river yearling and subyearling Chinook in 2009, although for these larger fish, biological effects of passage were typically expressed as increases in descaling rather than large increases in mortality. Thus, there is some evidence that improvements to gatewell flow conditions for Spring Creek subyearlings can be expected to improve passage conditions for run-of-river Chinook salmon juveniles.

During test series 1 in 2015, gatewell residence time was shorter at the upper 1% than the middle 1% operation. In 2013, this difference in passage time was even more pronounced, but the upper 1% operation was tested against the lower 1% during that study. Also in 2013, observed mortality was much higher at the upper 1% than during the lower 1% operation. In contrast, 2015 results from test series 1 showed significantly higher mortality at the middle 1% (standard gatewell configuration) than at the upper 1% operation (with flow-control plates and modified VBS). This outcome was especially pronounced during the first week of test series 1, when recapture rates were similar for both test groups.

Observed mortality was significantly lower and gatewell residence time significantly shorter for releases to slot 15A (upper 1% operation) than for those to slot 14A (middle1% operation) in test series 1. In contrast, results from evaluation of turbine reduction devices in 2013 showed significantly higher mortality and shorter passage time for releases at the upper 1% than at the lower 1% operation (Gilbreath et al. 2014).

During tests in 2015, 3-5% of tagged study fish were misrouted at the SbyC rotating gate. Such misrouting is typically caused by tag collision, wherein two or more tags are excited by the detection field of the monitor at the same time. Both tags emit tag codes simultaneously so that neither tag may be read by the transceiver. Consequently, the signal to activate the rotating gate for these fish is never received.

These events are not unexpected during periods when high numbers of tagged fish are arriving at the SbyC gate. Based on our experience in 2013, we anticipated that relatively high densities of fish might be present in the bypass system when run-of-river fish were passing the project during our studies. Therefore, we tried to minimize the incidence of tag collision in several ways.

First, on days when baseline groups were released to the downstream migrant channel, we timed releases so that baseline fish would have passed bypass system PIT-tag monitors before treatment release groups arrived. Second, we limited the total number of fish released to less than 300 per day to avoid overwhelming the SbyC system.

Third, we released fish groups in the morning to minimize tag collisions with run-of-river fish. This approach was certainly helpful; however, many study fish remained in the gatewells until evening, when encounters with run-of-river fish were unavoidable. Gatewell releases were typically separated by about 10 min due to logistical restraints, but this likely had a minimal effect on avoiding collisions.

Detection and recapture rates were relatively high for all release groups over the first week of test series 1. For fish released to turbine intake slot 14A (middle 1% operation), these rates remained high throughout the study. For the fish released to turbine intake slot 15A (upper 1% operation), detection and recapture rates dropped markedly in the middle of the study but recovered somewhat toward the end. Ultimately, detection and recpatures rates remained lower for releases to slot 15A.

The fate of test fish that were not recaptured is unknown. In the 2008-2009 studies, live fish were observed downstream of the VBS due to the failure of horizontal seals between the VBS sections. In 2013, it was common to see mortalities and bare tags impinged on the VBSs when they were raised. This year, no problems were noted with the VBS seals, river flow and debris levels much lower than normal, and no live fish were observed in the gatewell downstream of the VBS.

There were also almost no mortalities observed impinged on the VBSs when they were raised for cleaning twice per week during the study period. We believe most of the fish never detected or observed after release likely passed through the gap at the top of the STS or under the STS and passed through the turbines to the tailrace.

Another potential explanation for why fish were not detected or recaptured after release was that some study fish swam upstream and out of the gatewell intake into the forebay. This behavior was observed for one fish. This fish had been released to slot 14A (middle 1% operation) and was detected on the corner collector 9 d after release.

We believe this behavior was unusual and probably occurred at a very low rate. There is a high likelihood that any juvenile fish in this situation would eventually pass back down through the Second Powerhouse. In doing so, these fish would have a reasonably high likelihood of being detected either on the corner collector or in the JMF. An upstream escape scenario is even less likely for fish released to slot 15A (upper 1% operation), even though more fish from these groups were never detected after release.

The improbability of escape by swimming upstream (without later detection) leads us to believe that non-detected fish likely escaped through the gap in the vertical spaces above, along either side of, or under, the submersible traveling screen (STS). Furthermore, detections on the pile dike, estuary trawl, and avian colonies of fish not observed at Bonneville Dam suggest that many of these study fish survived passage at Bonneville Dam and river migration of at least 160 km to the estuary detection sites.

The fate of the undetected fish is perplexing, and since we do not know enough definitive information about their passage route, we cannot say either that they survived or were mortalities. The very limited data from estuary detections indicates that at least some of the fish did survive to the estuary, but does not allow a meaningful statistical analysis.

During studies in 2008, 2009, and 2013; dead fish and bare tags were commonly observed impinged on the VBSs when they were raised for cleaning. That was not the case in 2015, when mortalities and/or bare tags were not frequently observed on the VBSs. Also, far fewer bare tags were recovered from the sump at the approach to the primary dewatering structure in 2015.

In 2013, we recovered 294 bare tags near the primary dewatering structure from a total of 3,712 released fish. In 2015, only 62 bare tags were recovered at this structure from releases totaling 6,626 fish. Of those 62 bare tags 56 (90%) were from fish released at the middle 1% and 6 (10%) were from fish released at the upper 1% operation. This further breaks down to 47/51 tags during test series 1 and 9/11 from test series 2 were from fish released at the middle 1% operation. This contrasts to 2013, where of the 294 bare tags recovered, 290 (99%) were from fish that had been released at the upper 1% operation, and 4 were released at the lower 1%.

For fish in test series 2, gatewell residence time was similar for fish released into slot 14A compared to slot 15C, as noted above. Fish recaptured as mortalities at the juvenile facility tend to have longer gatewell residence times than those recaptured alive. For fish released into both slot 14A and 15C during test series 2, the distribution of gatewell egress times from release to recapture exhibited a longer "tail" than was observed during test series 1. This reflected a larger proportion of fish passing later in the study period and contributed to longer gatewell residence times than were noted for test series 1.

Mortality rates were quite low for both release locations from test series 2, though mortality was statistically higher for releases into slot 14A. Recapture proportions were high over the course of the study, and mortality rates were fairly consistent for both release locations through the study period.

Nevertheless, we believe that fish size had a minimal effect on the larger proportion of fish released to slot 15C that were not detected after release. As expected, fish size increased during the course of the study. However, the highest proportions of non-detected fish came after the first week of the study, but later decreased, even while fish size continued to increase. Furthermore, if fish size was the cause of non-detection, we would have observed more fish escaping from slot 14A as well, since fish from each replicate were the same size each day.

We believe that if fish had escaped the test gatewells in high numbers, we would have seen more than one detection at the corner collector. Likewise, if larger fish size explained the missed detections, we would have expected the trend of missed detections to continue or increase through test series 2, when study fish were even larger. We did not see that result. In fact, during test series 2, proportions of non-detected fish were relatively small, at 3% for releases to slot 14A and 5% for released to slot 15C.

Because we did not see a direct relationship between fish size and detection proportion and observed only one fish at the corner collector, we conclude that fish not detected at Bonneville Dam likely passed through the turbine unit, either through the gap at the top of the STS or under the STS. Recovery of PIT tags from these undetected fish on East Sand Island indicated that many of these fish survived to the estuary.

For fish released during test series 2 (14A vs. 15C), gatewell residence time was similar for both release locations and longer than those observed for fish in test series 1.

For approximately the first two-thirds of test series 2, live recaptures generally arrived before mortalities, as had occurred during test series 1. Yet for the last replicates of test series 2 overall, mortalities arrived earlier than live fish. In test series 2, the shape of the passage-time distribution was similar between 14A and 15C release groups, as was the median passage time. Observed mortality was much lower in test series 2 than in test series 1 for both treatment groups, although mortality was still significantly higher for releases to slot 14A than for those to 15C.

There was a disease incident at Spring Creek NFH with the second production release, which included the study fish used for test series 2. These fish were being treated for hexamita prior to release and were released one week earlier than originally planned. The disease was most prevalent in the smaller fish and in certain raceways.

Hatchery staff segregated fish for our study from the general population and moved them to troughs fed with spring water rather than the recirculating raceway water where they had been held. Mortality rates of fish during transport, handling, and tagging remained very low, and fish appeared healthy and vigorous and remained so throughout the study. Therefore, we do not believe that the hexamita incident affected study results.

# Conclusions and Recommendations

## Test Series 1

Turbine intake slot 15A was operated at the upper end of the 1% peak efficiency range (18.0-18.5 kcfs unit inflow) with flow-control plates and a modified VBS. Turbine intake slot 14A was operated at the middle of the 1% peak efficiency range (14.0-14.5 kcfs unit inflow) with no flow control and a standard VBS.

1) Spring Creek Hatchery subyearling Chinook salmon released to slot 15A had significantly lower observed mortality than cohorts released to slot 14A.

2) Proportions of detected and recaptured fish were significantly lower for releases to turbine intake unit slot 15A (upper 1% operation) than for releases to slot 14A (middle 1% operation). A majority of these fish were never accounted for; depending on the fate of these fish, our conclusion regarding mortality (above) may change.

3) Gatewell residence time was significantly longer for fish released into slot 14A (middle 1% operation) than for those released to slot 15A (upper 1% operation).

## Test Series 2

Turbine intake slot 15C was operated at the upper end of the 1% peak efficiency range with a modified VBS but with no flow-control plates. Turbine intake slot 14A was operated at the middle of the 1% peak efficiency range with no other modifications.

4) This second evaluation compared gatewell conditions in a modified slot (15C) with those in a slot representing standard conditions (14A). Again, lower mortality was observed for releases to the modified gatewell (slot 15C); however, the difference in mortality rates between release sites was much lower than observed in test series 1 and was not statistically significant.

5) Proportions of detected fish were not significantly different between releases to intake slot 15C (upper 1% operation) and those to slot 14A (middle 1% operation). Likewise, proportions of recaptured fish were not significantly different between groups.

6) Gatewell residence time was longer for fish released during test series 2 than for fish released during test series 1. However, there was no significant difference in gatewell passage time between fish released to slot 15C (upper 1% operation) and those released to slot 14A (middle 1% operation).

The stated biological goal of modifications to the juvenile bypass system at Bonneville Dam Second Powerhouse is to improve passage conditions for all juvenile salmon while maintaining or improving fish guidance efficiency (FGE). This goal has proven difficult to achieve: FGE depends on maintaining gatewell flows, while reducing adverse passage effects may require reducing these flows. However, if passage conditions can be improved for Spring Creek hatchery fish, the benefit of such improvement would likely include reduced mortality and descaling rates for other stocks of juvenile salmonids.

# Acknowledgments

Many people contributed to the successful completion of this study. Under the direction of Ricky Jackson, the Bonneville Project structural crew provided crane service to place release-hose support assemblies and move them between evaluation sites, as well as removing them at the conclusion of the study. This crew also raised the VBSs for inspection and cleaning twice each week during the study.

The Bonneville Project operations staff maintained flow at the levels prescribed during each test period. Staff at the BPA Reservoir Control Center made a significant effort to ensure we had the conditions necessary to achieve the flow rates needed for biological evaluation in an abnormally low water year.

Jonathan Rerecich of the Portland District U.S. Army Corps of Engineers served as our contracting officer's technical representative and Bonneville Project liaison for the project. His assistance coordinating with staff from project operations and the Reservoir Control Center was essential for the successful completion of the study, especially given the low river flows present during much of the study period. Tammy Mackey, also of Portland District USACE, helped us to meet requirements for researchers working at Bonneville Dam. Ida Royer was our point of contact and provided necessary assistance at the start of the study allowing us to meet Bonneville Project requirements.

With the leadership of Mark Ahrens and assistance of Mathew Maxey, staff of the U.S. Fish and Wildlife Service Spring Creek National Fish Hatchery provided test fish for the study. Hatchery staff were quite accommodating and provided essential support by holding test fish at their facility after production fish had been released. Susan Gutenberger of the U.S. Fish and Wildlife Service Lower Columbia River Fish Health Center provided the fish health certification necessary to obtain a fish transport permit.

Pacific States Marine Fisheries Commission Smolt Monitoring Program staff at the Juvenile Fish Monitoring Facility, led by Dean Ballinger, were helpful, and as usual, enjoyable to work beside. Nicole Tancreto assisted with the separation-by-code system at the juvenile facility, a task essential to the successful completion of the study.

Staff at ODFW, WDFW, and NOAA Fisheries Western Regional Office processed applications allowing us to handle fish for this study in an efficient and timely manner. Additional NOAA Fisheries staff including, Ron Marr of the Pasco Research Station provided fabrication and vital field support throughout the project. JoAnne Butzerin edited draft reports, improving the quality of this product.

Lila Charlton of Ocean Associates (formerly of NOAA Fisheries) processed recaptures of fish tagged and released above Lower Granite Dam by NOAA researcher Tiffani Marsh, and she also provided valuable assistance in processing recaptured fish from this study.

Finally, we thank Lyle Gilbreath for his contribution of expertise to this study, for his excellent work during previous biological evaluations at Bonneville Dam Second Powerhouse, and for his many years of diligent effort during a career dedicated to improving the outlook for salmonids in the Columbia River Basin.

# References


Ceballos, J. R., S. W. Pettit, J. L. McKern, R. R. Boyce, and D. F. Hurson. 1993. Fish transportation team annual report – FY 1992. Transport operations on the Snake and Columbia rivers. NOAA Technical Memorandum NMFS F/NWR-32.

Gilbreath, L. G., R. F. Absolon, B. P. Sandford, and D. Ballinger. 2014. Passage evaluation of Spring Creek Hatchery subyearling Chinook salmon at Bonneville Dam Second Powerhouse, 2013. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon. Available from www.nwfsc.noaa.gov/publications/scipubs/index.cfm (February 2016).

Gilbreath, L. G., B. P. Sandford, M. H. Gessel, D. A. Brege, and D. Ballinger. 2012. Condition and gatewell retention time of yearling and subyearling Chinook salmon guided from modified turbine intakes at Bonneville Dam Second Powerhouse, 2008-2009. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon. Available from www.nwfsc.noaa.gov/publications/scipubs/index.cfm (February 2016).

FPC (Fish Passage Center). 2007. Fish Passage Center annual report 2007. Report of the Columbia Basin Fish & Wildlife Authority to the Bonneville Power Administration, Portland, Oregon. Available from www.fpc.org/documents/FPC_Annual_Reports.html (February 2016).

FPC (Fish Passage Center). 2015. Fish Passage Center 2014 annual report. Report of the Columbia Basin Fish & Wildlife Authority to the Bonneville Power Administration, Portland, Oregon. Available from www.fpc.org/documents/FPC_Annual_Reports.html (February 2016).

HCE and ARL (Harbor Consulting Engineers, Inc. and Alden Research Laboratory, Inc.). 2015. Data Collection for B2 VBS Velocity Profiles at Bonneville Dam Second Powerhouse. Report to the U.S. Army Corps of Engineers, Portland, OR.

HCE and ARL (Harbor Consulting Engineers, Inc. and Alden Research Laboratory, Inc.). 2014. Data Collection for B2 VBS Velocity Profiles at Bonneville Dam Second Powerhouse. Report to the U.S. Army Corps of Engineers, Portland, OR.

HCE and ARL (Harbor Consulting Engineers, Inc. and Alden Research Laboratory, Inc.). 2013. Data collection report: water velocity measurements on vertical barrier screens with and without proof-of-concept turbulence reduction devices at the Bonneville Dam Second Powerhouse. Report of HCE and ARL to the U.S. Army Corps of Engineers, Portland District, Portland, OR.

PSMFC (Pacific States Marine Fisheries Commission). 1996. The Columbia Basin PIT Tag Information System (PTAGIS). PSMFC, Gladstone, Oregon. Available from www.ptagis.org/ (March 2014).

PSMFC (Pacific States Marine Fisheries Commission). 2015. P3 field tagging software. Available from www.ptagis.org/software/softwaredetails/p3 (February 2016).

USACE (U.S. Army Corps of Engineers). 2013. Bonneville Second Powerhouse fish guidance efficiency (FGE) Program post construction. Engineering documentation report of the U.S. Army Corps of Engineers, Portland, OR. Available from USACE Portland Technical Library http://a10127.eos-intl.net/A10127/ OPAC/Index.aspx (February 2016)

USFWS (U.S. Fish and Wildlife Service). 2014. Columbia River Gorge National Fish Hatchery Complex Annual Report, Fiscal Year 2013: Spring Creek National Fish Hatchery. Report of the U.S. Fish and Wildlife Service. Underwood, Washington.

Zar, J. H. 1999. 4th Ed. Biostatistical Analysis. Prentice and Hall, NJ. 663 pp.

# Appendix

Appendix Table 1a. Release and recapture data for test series 1, Spring Creek NFH subyearling Chinook salmon PIT tagged for evaluation of fish condition at Bonneville Dam Second Powerhouse in 2015. Test fish were recaptured and examined at the Second Powerhouse Juvenile Fish Monitoring Facility.

| Release date | Fish released (n) | Average fork length (mm) | Average weight (g) | Recaptured and examined: Alive (n) | Mortality (n) | Mortality (%) | Recapture (%) |
|---|---|---|---|---|---|---|---|
| **Turbine slot 14A releases** | | | | | | | |
| 1 Apr | 100 | n/a | n/a | 74 | 17 | 0.187 | 0.91 |
| 2 Apr | 94 | n/a | n/a | 72 | 10 | 0.122 | 0.87 |
| 3 Apr | 101 | 65 | n/a | 68 | 28 | 0.292 | 0.95 |
| 4 Apr | 100 | 66 | 3.1 | 67 | 23 | 0.256 | 0.90 |
| 5 Apr | 100 | 65 | 2.7 | 49 | 39 | 0.443 | 0.88 |
| 6 Apr | 102 | 65 | 3.1 | 62 | 32 | 0.340 | 0.92 |
| 7 Apr | 100 | 65 | 2.9 | 61 | 29 | 0.322 | 0.90 |
| 8 Apr | 99 | 67 | 3.0 | 71 | 16 | 0.184 | 0.88 |
| 9 Apr | 101 | 69 | 3.4 | 63 | 30 | 0.323 | 0.92 |
| 21 Apr | 116 | 71 | 3.5 | 86 | 12 | 0.122 | 0.84 |
| 23 Apr | 250 | 71 | 3.6 | 191 | 12 | 0.059 | 0.81 |
| 5 May | 125 | 73 | 4.1 | 114 | 4 | 0.034 | 0.94 |
| 7 May | 233 | 76 | 4.5 | 204 | 8 | 0.038 | 0.91 |
| Total/mean | 1,621 | 70 | 3.6 | 1,182 | 260 | 0.209 | 0.90 |
| **Turbine slot 15A releases** | | | | | | | |
| 1 Apr | 100 | n/a | n/a | 95 | 0 | 0.000 | 0.95 |
| 2 Apr | 99 | n/a | n/a | 38 | 1 | 0.026 | 0.39 |
| 3 Apr | 102 | 66 | n/a | 90 | 0 | 0.000 | 0.88 |
| 4 Apr | 100 | 64 | 3.1 | 87 | 4 | 0.044 | 0.91 |
| 5 Apr | 100 | 69 | 3.5 | 88 | 0 | 0.000 | 0.88 |
| 6 Apr | 100 | 70 | 3.5 | 84 | 0 | 0.000 | 0.84 |
| 7 Apr | 101 | 66 | 2.9 | 61 | 2 | 0.032 | 0.62 |
| 8 Apr | 100 | 68 | 3.1 | 56 | 3 | 0.051 | 0.59 |
| 9 Apr | 100 | 68 | 3.1 | 56 | 1 | 0.018 | 0.57 |
| 21 Apr | 115 | 71 | 3.6 | 43 | 4 | 0.085 | 0.41 |
| 22 Apr | 240 | 72 | 3.8 | 180 | 1 | 0.006 | 0.75 |
| 5 May | 125 | 75 | 4.4 | 97 | 1 | 0.010 | 0.78 |
| 6 May | 247 | 77 | 4.7 | 200 | 0 | 0.000 | 0.81 |
| Total/mean | 1,629 | 70 | 3.6 | 1,175 | 17 | 0.021 | 0.86 |
| **Collection channel releases** | | | | | | | |
| 5 Apr | 50 | 69 | 3.8 | 50 | 0 | 0.00 | 1.00 |
| 9 Apr | 29 | 70 | 3.7 | 29 | 0 | 0.00 | 1.00 |
| 7 May | 30 | 75 | 4.4 | 28 | 0 | 0.00 | 0.93 |
| Total/mean | 109 | 71 | 4.0 | 107 | 0 | 0.00 | 0.98 |

Appendix Table 1b. Release and recapture data for test series 2, Spring Creek NFH subyearling Chinook salmon PIT tagged for evaluation of fish condition at Bonneville Dam Second Powerhouse in 2015. Test fish were recaptured and examined at the Second Powerhouse Juvenile Fish Monitoring Facility.

| Release date | Fish released (n) | Average fork length (mm) | Average weight (g) | Recaptured and examined: Alive (n) | Mortality (n) | Mortality (%) | Recapture (%) |
|---|---|---|---|---|---|---|---|
| **Turbine slot 14A releases** | | | | | | | |
| 12 May | 131 | 75 | 4.5 | 119 | 2 | 0.017 | 0.92 |
| 13 May | 129 | 74 | 4.3 | 119 | 0 | 0.000 | 0.92 |
| 14 May | 123 | 77 | 4.8 | 112 | 2 | 0.018 | 0.93 |
| 15 May | 130 | 78 | 5.0 | 118 | 3 | 0.025 | 0.93 |
| 18 May | 130 | 80 | 5.8 | 121 | 2 | 0.016 | 0.95 |
| 19 May | 130 | 81 | 5.5 | 117 | 5 | 0.041 | 0.94 |
| 20 May | 129 | 78 | 5.1 | 123 | 2 | 0.016 | 0.97 |
| 21 May | 130 | 77 | 4.9 | 110 | 9 | 0.076 | 0.92 |
| 22 May | 140 | 80 | 5.4 | 4 | 0 | | 0.03 |
| 27 May | 130 | 83 | 6.2 | 123 | 0 | 0.000 | 0.95 |
| 28 May | 130 | 82 | 5.8 | 113 | 2 | 0.017 | 0.88 |
| 29 May | 135 | 82 | 5.6 | 130 | 1 | 0.008 | 0.97 |
| Total/mean | 1,567 | 79 | 5.2 | 1,309 | 28 | 0.021 | 0.86 |
| **Turbine slot 15C releases** | | | | | | | |
| 12 May | 131 | 75 | 4.6 | 123 | 0 | 0.000 | 0.94 |
| 13 May | 131 | 75 | 4.5 | 125 | 1 | 0.008 | 0.96 |
| 14 May | 118 | 76 | 4.7 | 110 | 0 | 0.000 | 0.93 |
| 15 May | 134 | 77 | 4.7 | 125 | 2 | 0.016 | 0.95 |
| 18 May | 130 | 77 | 5.2 | 120 | 2 | 0.016 | 0.94 |
| 19 May | 130 | 76 | 4.9 | 112 | 2 | 0.018 | 0.88 |
| 20 May | 130 | 79 | 5.2 | 102 | 0 | 0.000 | 0.78 |
| 21 May | 130 | 79 | 5.1 | 123 | 1 | 0.008 | 0.95 |
| 22 May | 142 | 79 | 5.2 | 1 | 0 | | 0.01 |
| 27 May | 130 | 84 | 5.2 | 105 | 0 | 0.000 | 0.81 |
| 28 May | 130 | 81 | 5.8 | 115 | 0 | 0.000 | 0.88 |
| 29 May | 134 | 82 | 5.6 | 127 | 0 | 0.000 | 0.95 |
| Total/mean | 1,570 | 78 | 5.1 | 1,288 | 8 | 0.006 | 0.83 |
| **Collection channel releases** | | | | | | | |
| 14 May | 40 | 80 | 5.6 | 39 | 0 | 0.000 | 0.98 |
| 21 May | 40 | 79 | 5.5 | 37 | 0 | 0.000 | 0.93 |
| 28 May | 50 | 84 | 6.5 | 46 | 0 | 0.000 | 0.92 |
| Total/mean | 130 | 81 | 5.9 | 122 | 0 | 0.000 | 0.94 |

Appendix Table 2a. Turbine 14 and 15 operating conditions during test series 1 releases of subyearling Spring Creek NFH Chinook salmon at Bonneville Dam Second Powerhouse in 2015. Middle 1% and upper 1% are turbine operational settings within the 1% peak efficiency range. Values for operating head are in feet msl. Data are for 24-hour time blocks after release. Start times are in Pacific Daylight Time.

| Release date | Start time (PDT) | Unit flow (kcfs) | | | Average head (ft) |
|---|---|---|---|---|---|
| | | Average | Minimum | Maximum | |
| **Turbine Unit 14—middle 1%** | | | | | |
| 1 Apr | 0815 | 14.5 | 14.0 | 15.1 | 54.9 |
| 2 Apr | 0815 | 14.6 | 14.0 | 15.0 | 55.0 |
| 3 Apr | 0825 | 14.5 | 14.0 | 15.1 | 56.4 |
| 4 Apr | 0815 | 14.5 | 14.1 | 14.9 | 56.4 |
| 5 Apr | 0840 | 14.5 | 13.6 | 15.2 | 55.8 |
| 6 Apr | 0910 | 14.6 | 14.1 | 15.3 | 55.4 |
| 7 Apr | 0815 | 14.4 | 13.9 | 14.9 | 56.1 |
| 8 Apr | 0830 | 14.6 | 13.9 | 15.0 | 57.0 |
| 9 Apr | 0955 | 14.5 | 13.6 | 15.3 | 58.7 |
| 21 Apr | 0845 | 12.0 | 0 | 15.3 | 56.5 |
| 23 Apr | 0905 | 14.7 | 14.0 | 15.6 | 58.8 |
| 5 May | 0810 | 14.4 | 14.1 | 15.0 | 57.1 |
| 7 May | 0925 | 14.5 | 14.1 | 14.9 | 57.3 |
| **Turbine Unit 15—upper 1%** | | | | | |
| 1 Apr | 0825 | 18.2 | 17.3 | 18.9 | 54.9 |
| 2 Apr | 0825 | 18.2 | 17.0 | 18.7 | 55.0 |
| 3 Apr | 0815 | 18.2 | 17.2 | 18.7 | 56.4 |
| 4 Apr | 0830 | 18.1 | 17.8 | 18.4 | 56.4 |
| 5 Apr | 0835 | 18.2 | 17.7 | 18.9 | 55.8 |
| 6 Apr | 0840 | 18.4 | 17.8 | 18.9 | 55.4 |
| 7 Apr | 0840 | 18.3 | 17.9 | 18.7 | 56.1 |
| 8 Apr | 0825 | 18.2 | 17.6 | 18.7 | 57.0 |
| 9 Apr | 0945 | 17.7 | 16.7 | 18.3 | 58.7 |
| 21 Apr | 0855 | 18.2 | 17.4 | 18.9 | 56.8 |
| 22 Apr | 0815 | 17.9 | 16.7 | 18.6 | 58.1 |
| 5 May | 0815 | 18.2 | 17.8 | 18.8 | 57.1 |
| 6 May | 0815 | 18.3 | 17.7 | 18.8 | 57.0 |

Appendix Table 2b. Turbine 14 and 15 operating conditions during test series 2 releases of subyearling Spring Creek NFH Chinook salmon at Bonneville Dam Second Powerhouse in 2015. Middle 1% and upper 1% are turbine operational settings within the 1% peak efficiency range. Values for operating head are in feet msl. Data are for 24-hour time blocks after release. Start times are in Pacific Daylight Time.

| Date | Start time (24-h clock) | Unit flow (kcfs) | | | Average head (ft) |
|---|---|---|---|---|---|
| | | Average | Minimum | Maximum | |
| Turbine Unit 14—middle 1% | | | | | |
| 12 May | 0830 | 14.4 | 13.5 | 15.0 | 56.8 |
| 13 May | 0820 | 14.5 | 14.0 | 14.9 | 56.0 |
| 14 May | 0840 | 14.5 | 14.1 | 15.2 | 54.9 |
| 15 May | 0805 | 14.3 | 13.8 | 14.7 | 55.2 |
| 18 May | 0820 | 14.6 | 14.2 | 15.1 | 54.1 |
| 19 May | 0840 | 14.5 | 14.1 | 14.9 | 54.8 |
| 20 May | 0805 | 14.5 | 14.0 | 15.0 | 54.6 |
| 21 May | 0840 | 14.5 | 13.9 | 15.0 | 54.0 |
| 22 May | 0825 | 14.5 | 14.0 | 15.0 | 55.4 |
| 27 May | 0815 | 14.5 | 13.9 | 15.6 | 55.0 |
| 28 May | 0845 | 14.5 | 14.1 | 15.0 | 55.1 |
| 29 May | 0815 | 14.5 | 14.0 | 15.4 | 55.7 |
| Turbine Unit 15—upper 1% | | | | | |
| 12 May | 0840 | 18.2 | 17.4 | 18.8 | 56.8 |
| 13 May | 0810 | 18.3 | 17.9 | 18.8 | 56.0 |
| 14 May | 0830 | 18.3 | 17.9 | 18.8 | 54.9 |
| 15 May | 0815 | 18.1 | 17.6 | 18.6 | 55.2 |
| 18 May | 0840 | 18.3 | 17.8 | 18.9 | 54.1 |
| 19 May | 0830 | 18.2 | 17.8 | 18.6 | 54.8 |
| 20 May | 0815 | 18.2 | 17.7 | 18.6 | 54.6 |
| 21 May | 0850 | 18.3 | 17.5 | 18.8 | 54.0 |
| 22 May | 0815 | 18.3 | 14.4 | 18.9 | 55.4 |
| 27 May | 0905 | 18.2 | 17.5 | 18.9 | 55.0 |
| 28 May | 0835 | 18.3 | 17.6 | 18.8 | 55.1 |
| 29 May | 0825 | 18.2 | 16.0 | 19.0 | 55.7 |

Appendix Table 3a. Summary of test series 1 results of subyearling Spring Creek NFH Chinook salmon released at Bonneville Dam Second Powerhouse in 2015 into Turbine intake 14A.

| **Releases to slot 14A** | | | | | |
|---|---|---|---|---|---|
| Release date | Release number | Observed proportion[a] | Recaptured proportion[b] | Observed mortality proportion[c] | Median gatewell residence time (d) |
| 4/1 | 100 | 0.930 | 0.978 | 0.187 | 0.106 |
| 4/2 | 94 | 0.872 | 1.000 | 0.122 | 0.057 |
| 4/3 | 101 | 0.960 | 0.990 | 0.292 | 0.263 |
| 4/4 | 100 | 0.920 | 0.978 | 0.256 | 0.038 |
| 4/5 | 100 | 0.920 | 0.957 | 0.443 | 0.347 |
| 4/6 | 102 | 0.951 | 0.969 | 0.340 | 0.463 |
| 4/7 | 100 | 0.930 | 0.968 | 0.322 | 0.251 |
| 4/8 | 99 | 0.960 | 0.916 | 0.184 | 0.044 |
| 4/9 | 101 | 0.970 | 0.949 | 0.323 | 0.289 |
| 4/21 | 116 | 0.879 | 0.961 | 0.122 | 0.506 |
| 4/23 | 250 | 0.912 | 0.890 | 0.059 | 0.487 |
| 5/5 | 125 | 0.992 | 0.952 | 0.034 | 0.544 |
| 5/7 | 233 | 0.966 | 0.942 | 0.038 | 0.495 |
| Mean | | 0.936 | 0.958 | 0.209 | 0.299 |
| SE | | 0.008 | 0.008 | 0.036 | 0.053 |

a Observed proportion is the proportion of released fish that were detected at the JFMF full flow PIT detectors.

b Recaptured proportion is the proportion of those fish that were observed at the full flow detectors that were recaptured by the SbyC system.

c Observed mortality proportion is the proportion of those fish that were recaptured, that were mortalities upon re-examination.

Appendix Table 3b. Summary of test series 1 results for subyearling Spring Creek NFH Chinook salmon released at Bonneville Dam Second Powerhouse in 2015 into Turbine intake 15A.

| Releases to slot 15A | | | | | |
|---|---|---|---|---|---|
| Release date | Release number | Observed proportion[a] | Recaptured proportion[b] | Observed mortality proportion[c] | Median gatewell residence time (d) |
| 4/1 | 100 | 0.950 | 1.000 | 0.000 | 0.095 |
| 4/2 | 99 | 0.914 | 0.975 | 0.026 | 0.035 |
| 4/3 | 102 | 0.882 | 1.000 | 0.000 | 0.054 |
| 4/4 | 100 | 0.910 | 1.000 | 0.044 | 0.040 |
| 4/5 | 100 | 0.890 | 0.989 | 0.000 | 0.057 |
| 4/6 | 100 | 0.840 | 1.000 | 0.000 | 0.175 |
| 4/7 | 101 | 0.634 | 0.984 | 0.032 | 0.106 |
| 4/8 | 100 | 0.620 | 0.952 | 0.051 | 0.076 |
| 4/9 | 100 | 0.580 | 0.983 | 0.018 | 0.068 |
| 4/21 | 115 | 0.443 | 0.922 | 0.085 | 0.075 |
| 4/22 | 240 | 0.783 | 0.963 | 0.006 | 0.522 |
| 5/5 | 125 | 0.800 | 0.980 | 0.010 | 0.537 |
| 5/7 | 247 | 0.834 | 0.971 | 0.000 | 0.543 |
| Mean | | 0.775 | 0.978 | 0.021 | 0.183 |
| SE | | 0.043 | 0.006 | 0.007 | 0.056 |

a Observed proportion is the proportion of released fish that were detected at the JFMFfull flow PIT detectors.

b Recaptured proportion is the proportion of those fish that were observed at the full flow detectors that were recaptured by the SbyC system.

c Observed mortality proportion is the proportion of those fish that were recaptured, that were mortalities upon re-examination.

Appendix Table 4a. Summary of results from test series 2 for subyearling Spring Creek NFH Chinook salmon released at Bonneville Dam Second Powerhouse in 2015 into Turbine intake 14A.

| Releases to slot 14A | | | | | |
|---|---|---|---|---|---|
| Release date | Release number | Observed proportion[a] | Recaptured proportion[b] | Observed mortality proportion[c] | Median gatewell residence time (days) |
| 5/12 | 131 | 0.985 | 0.938 | 0.017 | 0.532 |
| 5/13 | 129 | 0.984 | 0.937 | 0.000 | 0.044 |
| 5/14 | 123 | 0.984 | 0.942 | 0.018 | 0.392 |
| 5/15 | 130 | 0.954 | 0.976 | 0.025 | 0.548 |
| 5/18 | 130 | 0.977 | 0.969 | 0.016 | 0.545 |
| 5/19 | 130 | 0.985 | 0.953 | 0.041 | 0.527 |
| 5/20 | 129 | 0.984 | 0.984 | 0.016 | 0.393 |
| 5/21 | 130 | 0.954 | 0.960 | 0.076 | 0.288 |
| 5/22[d] | 140 | 0.986 | | | 0.407 |
| 5/27 | 130 | 0.992 | 0.953 | 0.000 | 0.369 |
| 5/28 | 130 | 0.946 | 0.935 | 0.017 | 0.548 |
| 5/29 | 135 | 0.993 | 0.978 | 0.008 | 0.568 |
| Mean | | 0.977 | 0.957 | 0.021 | 0.430 |
| SE | | 0.005 | 0.005 | 0.006 | 0.044 |

a Observed proportion is the proportion of released fish that were detected at the JFMF full flow PIT detectors.

b Recaptured proportion is the proportion of those fish that were observed at the full flow detectors that were recaptured by the SbyC system.

c Observed mortality proportion is the proportion of those fish that were recaptured, that were mortalities upon re-examination.

d Most fish from this release were not diverted by the SbyC system.

Appendix Table 4b. Summary of results from test series 2 for subyearling Spring Creek NFH Chinook salmon released at Bonneville Dam Second Powerhouse in 2015 into Turbine intake 15C.

| Releases to slot 15C | | | | | |
|---|---|---|---|---|---|
| Release date | Release number | Observed proportion[a] | Recaptured proportion[b] | Observed mortality proportion[c] | Median gatewell residence time (days) |
| 5/12 | 131 | 0.954 | 0.984 | 0.000 | 0.345 |
| 5/13 | 131 | 0.962 | 1.000 | 0.008 | 0.368 |
| 5/14 | 118 | 0.983 | 0.948 | 0.000 | 0.337 |
| 5/15 | 134 | 0.985 | 0.962 | 0.016 | 0.511 |
| 5/18 | 130 | 0.969 | 0.968 | 0.016 | 0.497 |
| 5/19 | 130 | 0.915 | 0.958 | 0.018 | 0.633 |
| 5/20 | 130 | 0.815 | 0.962 | 0.000 | 0.296 |
| 5/21 | 130 | 0.962 | 0.992 | 0.008 | 0.545 |
| 5/22[d] | 142 | 0.944 | | | 0.567 |
| 5/27 | 130 | 0.954 | 0.847 | 0.000 | 0.518 |
| 5/28 | 130 | 0.962 | 0.920 | 0.000 | 0.545 |
| 5/29 | 134 | 0.993 | 0.955 | 0.000 | 0.475 |
| Mean | | 0.950 | 0.954 | 0.006 | 0.470 |
| SE | | 0.014 | 0.013 | 0.002 | 0.031 |

a Observed proportion is the proportion of released fish that were detected at the JFMF full flow PIT detectors.

b Recaptured proportion is the proportion of those fish that were observed at the full flow detectors that were recaptured by the SbyC system.

c Observed mortality proportion is the proportion of those fish that were recaptured, that were mortalities upon re-examination.

d Most fish from this release were not diverted by the SbyC system.