# Lewis River Fish Passage Program
# 2016 Annual Report

FERC Project Nos. 935, 2071, 2111, 2213

Swift Reservior Floating Surface Collector – 2016
Photo by Jessica Kimmick



***PacifiCorp***
***&***
***Public Utility District No.1 of Cowlitz County***



***April 4, 2017***

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** Not yet submitted by consultant*

# EXECUTIVE SUMMARY

The purpose of this report is to document results of the field assessments associated with implementation of the fish passage program in the existing Lewis River Aquatic Monitoring and Evaluation Plan[1] (M&E Plan) during 2016. The M&E Plan was developed as part of the Settlement Agreement to evaluate performance measures outlined in the new Licenses. These Licenses were issued to PacifiCorp and Cowlitz PUD for operation of the North Fork Lewis Hydroelectric Project on 26 June 2008. This report summarizes both upstream and downstream fish passage and collection metrics as well as providing an overview of environmental conditions and any key procedural changes that occurred in 2016. The following is a brief summary of relevant performance metrics reported on in this report:

| Description | M&E Obj. | Performance Goal | 2016 Data | Summary |
|---|---|---|---|---|
| Number of Juveniles Passing Eagle Cliff During Screw Trap Operations | Obj. 7 Task 7.1 | Monitoring | 7,164 coho<br>3,832 steelhead<br>77 Chinook<br>1,104 cutthroat | Estimates of the total number of juvenile coho, Chinook, steelhead, and cutthroat were made over a 13-week period using screw trap catch information. The trap was located at the head of Swift Reservoir at Eagle Cliff. |
| Number of Juveniles Entering Swift Reservoir | Obj. 7 Task 7.2 | Monitoring | 189,999 coho<br>NA Chinook<br>14,087 steelhead<br>5,442 cutthroat | Estimates of the total number of juvenile coho, steelhead, and cutthroat that entered Swift Reservoir during 2016. |
| Fish Numbers Collected at the Swift Floating Surface Collector (FSC) | Obj. 6 | Monitoring | Various | A total 73,539 salmonids were captured by the FSC in 2016. Of these fish, 68,175 were transported and released downstream of Merwin Dam. |
| Juvenile Migration Timing | Obj. 8 | Monitoring | Various | Overall, the run timing in 2016 followed a normal spring time distribution for rivers west of the Cascade Crest. The peak spring out-migration period generally occurred from the first of April through June. Within this time frame, 73% of the coho, 92% of the steelhead and 73.5% of the cutthroat were collected relative to the total annual catch. From the first of January to the end of March, 77% of the annual spring Chinook catch passed, |
| FSC Collection Efficiency (CE) | Obj. 2 | Juvenile Collection Efficiency > 95% | Combined 29.3%<br>Coho 30.6%<br>Chinook < 1.0%<br>Steelhead 23.5% | In 2016, CE was evaluated using acoustic telemetry. Of the 199 tagged fish released at the head of Swift Reservoir, 116 were detected in the Zone of Influence and 34 were successfully collected at the FSC for an overall CE estimate of 29.3%. |
| Swift FSC Injury | Obj. 5 | Smolts and Fry < 2% | Fry (0.0%)<br>Smolt (0.7%) | Annual injury rates for all juvenile salmonid species met the required performance standard of 2.0%. |

[1] Revisions to the M&E Plan began in 2015, and at the time of this document, are in final review for approval. The methods used in this report following the revised methods for the M&E Plan dated 2016.

| Description | M&E Obj. | Performance Goal | 2016 Estimate | Summary |
|---|---|---|---|---|
| Swift FSC Survival | Obj 4. | Fry > 98.0%<br>Smolt > 99.5% | Fry (100%)<br>Smolt (97.6%) | Overall, the combined survival rate for salmonid fry (100%) met the performance standard of 98%; however, the combined survival rates for all juvenile salmonid species (97.6%) was slightly lower than the required performance standard of 99.5 percent. |
| Overall Downstream Survival (ODS) | Obj. 1 | > 80% | Coho 33%<br>Chinook < 1.0%<br>Steelhead 15%<br>Cutthroat 4.5% | During 2016 686 coho, 79 steelhead, 22 cutthroat, and 2 Chinook were tagged and released for the ODS study. Of these fish, 227 coho, 0 Chinook, 12 steelhead, and 1 cutthroat were recaptured at the FSC and passed downstream. |
| Fish Numbers Collected at the Merwin Fish Collection Facility | Obj. 11 | Monitoring | Various | A total 23,570 fish were captured at the Merwin Trap in 2016. Of these fish, a total of 772 blank wire tag winter steelhead, 4,111 early coho, 3,235 late coho, and 73 cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program. |
| Adult Passage Survival | Obj. 9 | 99.50% | Coho 99.7%<br>Chinook NA<br>Steelhead 99.9%<br>Cutthroat 100% | All cutthroat survived the trapping and transport processes resulting in a UPS of 100 percent. One blank wire tag winter steelhead mortality wasobserved at the Merwin fish sorting facility, resulting in a 99.9 percent UPS. Twenty coho mortalities were observed resulting in a 99.7 percent UPS. No spring Chinook were transported upstream in 2016. |
| Adult Trap Efficiency (ATE) | Obj. 10 | > 98% | Coho NA<br>Chinook NA<br>Steelhead 73% | The second year of evaluation was completed in 2016 for blank wire tag winter steelhead and was found to be 73 percent. Coho and Chinook were not evaluated in 2016. |

# 1.0 INTRODUCTION

The North Fork Lewis Hydroelectric Project begins about 10 miles east of Woodland, Washington (Figure 1.0-1), and consists of four impoundments. The sequence of the four Lewis River projects upstream of the confluence of the Lewis and Columbia rivers is: Merwin, Yale, Swift No. 2, and Swift No.1. These four projects are licensed separately by the Federal Energy Regulatory Commission (FERC). Merwin (FERC No. 935), Yale (FERC No. 2071), and Swift No. 1 (FERC No. 2111) are owned and operated by PacifiCorp. Swift No. 2 (FERC NO. 2213) is owned by Public Utility District No. 1 of Cowlitz County (Cowlitz PUD) and is operated by PacifiCorp under contract with Cowlitz PUD in coordination with the other hydroprojects. Combined, the Lewis River project has a generation capacity of 606 megawatts.

On 26 June 2008, PacifiCorp and Cowlitz PUD were issued an Order by FERC approving the Settlement Agreement and granting new licenses for the North Fork Lewis River Hydroelectric Projects. Among the conditions contained in each License was a requirement for reintroducing anadromous salmonids and providing fish passage upstream of Merwin Dam and downstream of Swift No. 1 Dam. The overarching goal of this comprehensive reintroduction program is to achieve genetically viable, self-sustaining, naturally reproducing, harvestable populations of anadromous salmonids upstream of Merwin Dam. The target species identified in the Settlement Agreement for reintroduction are spring Chinook salmon (*Oncorhynchus tshawytscha)*, early-run (S-type) coho salmon (*O. kisutch)*, and winter steelhead (*O. mykiss*).

The Settlement Agreement called for a phased approach for reintroduction that occurs over a seventeen year period following issuance of the new Licenses. The phased approach provides for a carefully devised plan to protect the listed species and to verify effectiveness of the passage facilities while allowing for the reintroduction program to take effect. Among the tasks identified for Phase I of the reintroduction plan were establishing a downstream passage facility in the forebay of Swift No.1 Dam and making upgrades to the existing adult fish capture facility at Merwin Dam. Subsequent phases would establish facilities for both upstream and downstream passage at Merwin, Yale, and Swift No.1 Dams, with fish ultimately spawning and rearing naturally throughout the project area. A decision on whether subsequent phases are implemented is anticipated in early 2017.

The Lewis River Aquatic Monitoring and Evaluation (M&E) Plan (PacifiCorp and Cowlitz PUD 2010) was developed as part of the Settlement Agreement to evaluate performance measures outlined in the new Licenses. The primary focus of the plan is to provide methods for monitoring and evaluating the fish passage program. In accordance with the Settlement Agreement, the Licensees shall Consult with the Aquatic Coordination Committee (ACC) as necessary, but no less often than every five years, to determine if modifications to the M&E Plan are warranted (SA 9.1). Revisions to the M&E Plan are currently ongoing and are scheduled to be completed by early 2017. (This report follows updated methods outlined in the revised M&E Plan that is currently in review.) The purpose of this report is to document results of the field assessments associated with implementation of the fish passage program in the existing M&E Plan during 2016.

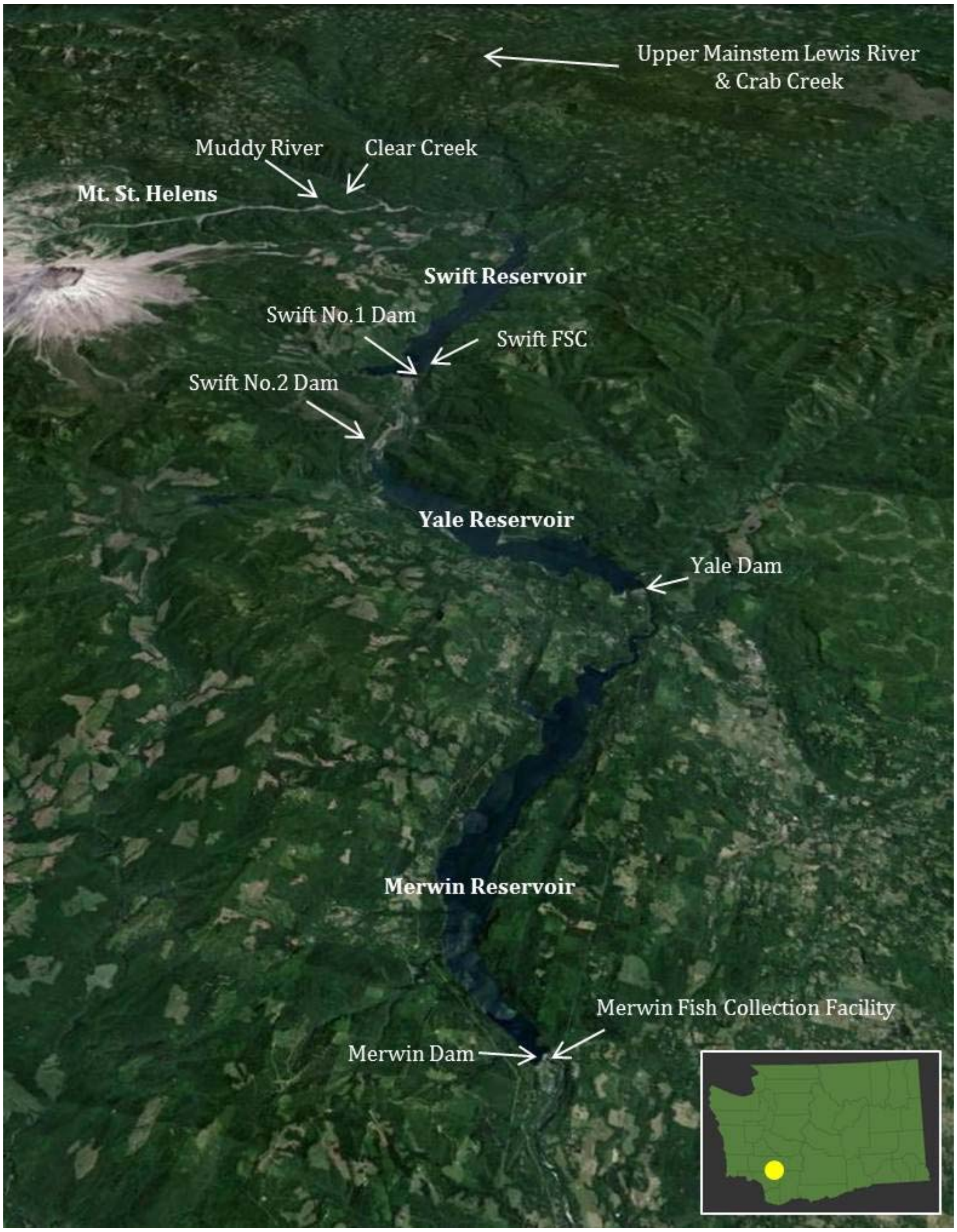



**Figure 1.0-1: An overview of key features of the North Fork Lewis River Hydroelectric Project area located in Southwest, Washington.**

Some noteworthy environmental conditions and procedural changes occurred in 2016. These items are summarized below:

- *Minimum Flow Requirement Below Merwin Dam:* During calendar year 2016, flows for the Merwin Project were modified from those stipulated in the June 26, 2008 FERC license. In response to low snowpack in the 2015/2016 winter and persistent dry weather conditions flows were modified from June 4$^{th}$, 2016 at 11:30 am until June 30$^{th}$ at midnight. Minimum flow was reduced from 2,700 cfs to 2,300 cfs in order to preserve water during the fall for fish spawning (Figure1.0-2). Flow modifications were agreed upon by the Lewis River Flow Coordination Committee (FCC).

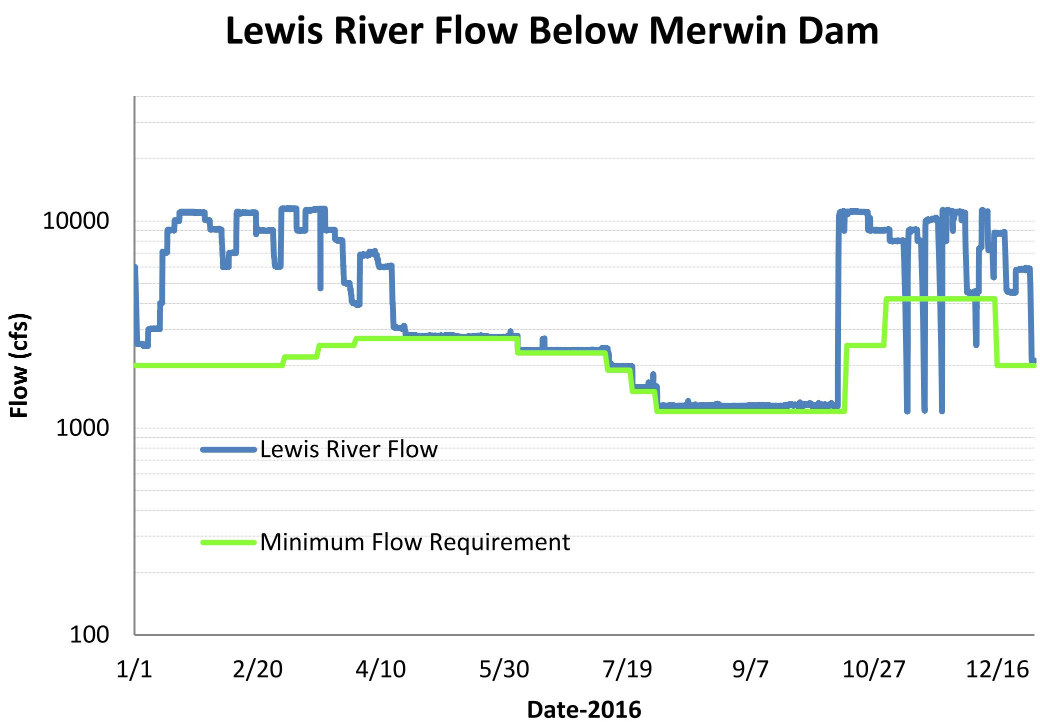



**Figure 1.0-2: Lewis River flow below Merwin Dam as recorded by USGS gage (14220500 Ariel WA). Minimum flow requirements for 2016 requirements are also shown. The sharp 'dips' in flow during November are scheduled drawdowns associated with WDFW fall Chinook surveys.**

- *FSC Summer Outage and Maintenance Period:* In March 2015, the ACC accepted operational changes which allowed for the FSC to be turned off during warm reservoir conditions that occur in the summer (Lewis River Fish Passage Program Annual Report 2015). This was done in support of data that indicated that once reservoir temperatures reach approximately 18 ºC, catch rates of fish declined precipitously. Those fish that were collected also experienced high levels of mortality. Annual maintenance activities will be performed during this summer outage period. It was also decided that while the FSC was offline, operation of the Merwin Trap would be changed from a seven (7) day per week schedule to a five (5) day per week schedule (Lewis River Fish Passage Program Annual Report 2015). This temporary scheduled allowed for the fish crowder and lift assembly to remain operational seven (7) days per week, however daily sorting of fish would only occur Monday through Friday. These operational changes were also done in 2016.

- *Modification of the Supplementation Protocols for Adult Coho Transported Upstream of Swift Dam:* In July 2015, the Hatchery and Supplementation (H&S) subgroup met to discuss the protocol for adult coho supplementation upstream of Swift Dam in fall 2015.

As part of this discussion, several important modifications were proposed and were ultimately accepted by the ACC during the August 2015 meeting. These strategies were again implemented for adult coho transported above Swift Dam in fall 2016. A detailed description of these modifications can be found in the Lewis River Fish Passage Program Annual Report 2015 and briefly described below:

  - Reduction in the number of coho supplemented from 9,000 to 7,500 total adults upstream of Swift Dam;
  - The addition of late (Type – N) coho as a supplementation species;
  - Extending the upstream transport schedule to include both early (Type – S) and late (Type – N) stocks of adults coho.

- *Releases of Acclimation Fish Changed from Spring Releases to Fall Releases:* During their June 2015 meeting, the ACC agreed that releasing acclimation fish earlier in the fall is a better strategy and more akin to the natural out-migration behavior that has been observed in the upper basin. It was also determined that fish released in the fall would be held a shorter amount of time in the hatchery and thus less susceptible to disease (e.g., Bacterial Kidney Disease – BKD) that has been observed in previous years. Consequently, it was agreed that fall releases of acclimation fish would be implemented moving forward. In total , approximatley 29,900 spring Chinook were released in the upper basin upstream of Swift Reservior from mid-September through mid-October. (Table 1.0-1).

- *Outmigration Timing of Directly Released Acclimation Fish:* During the fall of 2016 all spring Chinook acclimation fish were directly released into the Upper Lewis River near Crab Creek, the Muddy River near the Forest Road 25 bridge, Clear Creek near the Forest Road 93 bridge, and Drift Creek (Table 1.0-1). A portion of these fish were PIT tagged and the residency time they spent in tributaries was monitored through stationary PIT antennae receivers to assess whether direct releasing of acclimation fish is a viable option. The finding of this evaluation are reported in Appendix A.

**Table 1.0-1. Summary of acclimation fish released into the Upper Lewis River Basin in 2016. Number in parenthesis represents amount of fish that were PIT tagged in each group. FDX represents full duplex PIT tag and HDX represents half duplex PIT tag.**

| | 2016 Spring Chinook Acclimation Releases | | | | |
|---|---|---|---|---|---|
| | **Clear Creek** | **Muddy River** | **Crab Creek** | **Drift Creek** | |
| | **8,000 (500 FDX)**<br>Released 9/16<br>**1,850 (300 HDX)**<br>Released 9/28<br>**200 (200 HDX)**<br>Released 10/12/16 | **2,300 (2300 FDX)**<br>Released 9/22<br>**1,850 (300 HDX)**<br>Released 9/30<br>**200 (200 HDX)**<br>Released 10/13/16 | **15,000**<br>Released 9/15 | **500 (100 FDX)**<br>Released 9/14 | |
| **Total** | **10,050 (500 FDX, 500 HDX)** | **4,350 (2400 FDX, 500 HDX)** | **15,000** | **500 (100 FDX)** | **29,900 (2900 FDX, 1000 HDX)** |

# 2.0 PASSAGE FACILITIES

## 2.1 Swift Reservoir Floating Surface Collector

The Swift Reservoir Floating Surface Collector (FSC) began daily operations on December 26, 2012. The facility is located at the south end of Swift Dam near the turbine intake (Figure 2.1-1), and consists of three primary structures:

- Fish Collection Barge
- Truck Access Trestle and Mooring Tower
- Barrier Net and Net Transition Structure

The Swift Floating Surface Collector is a floating barge that measures 170 feet long, 60 feet wide and 53 feet tall. The purpose of the FSC is to provide attraction flow at the surface of the reservoir where juvenile salmonids are migrating. Fish enter the FSC via the Net Transition Structure (NTS), which funnels water and fish into an artificial stream channel created by electric pumps. The stream channel then entrains and guides fish into the collection facility that automatically sorts fish by life-stage (i.e., fry, smolt, and adult) and then routes them to holding tanks for biological sampling and transport downstream[2]. The artificial stream channel is maintained at a capture velocity of approximately 7 feet per second (fps) with 600 cubic feet per second (cfs) attraction flow during normal operations (80% of full flow capacity).

[2] Following transport downstream, smolts are to be transferred into release ponds located near Woodland, WA. Fish are held in these ponds for 24-hours before being allowed to volitionally enter the river. As of December 2016, these ponds have not been constructed due to permitting delays. Fish transported downstream in 2016 were released directly in the lower river.

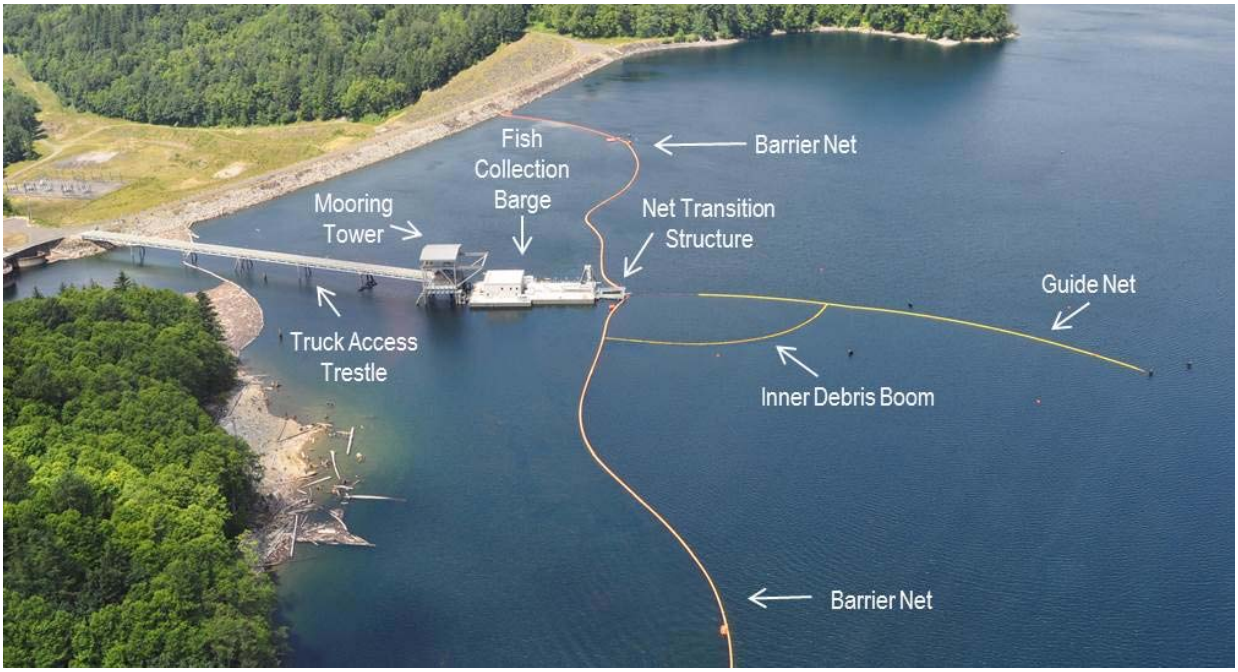



**Figure 2.1-1: Aerial photo of the Swift Floating Surface Collector.**

The purpose of the 660-foot access trestle is to provide fish transport trucks access to the 280 foot tall mooring tower. The mooring tower doubles as a hopper-to-truck fish transfer structure, allowing operators to move fish from the FSC to the truck across a broad range of reservoir surface elevations[3].

The portion of the exclusion net that is located perpendicular to the front of the FSC is approximately 1,700 feet long and consists of three distinct vertical panel materials. The upper section of the net consists of a solid material running 0-15 feet below the surface. The middle net section (15-30 feet) consists of a fine net material (Dyneema™) with 1/8-inch mesh opening. The lower most section (30 feet and beyond) is also constructed of Dyneema™ with 3/8-inch mesh opening. In addition to the forward-facing exclusion net, there are two side nets that begin at each of the turning points and extend to shore. Each side net is constructed of nylon material. The upper portion (0-15 feet) of the net has a mesh opening of 1/8-inch and the lower portion (15 feet and beyond) has a mesh opening of 3/8-inch.

Soon after the FSC began operation in late December 2012, it was determined that the exclusion net sustained damage during severe weather conditions. The extent of this damage was evaluated with a number of dive and ROV surveys of the net beginning in early February 2013. It was determined that the net separated at both north and south turning points. These tears compromised the effectiveness of the net throughout the 2013 migration season. Efforts to repair the net began in December 2013 and were completed by April 2014. During this repair period, the FSC was turned off. The FSC resumed operation on April 1, 2014.

In March 2016, a guide net was installed at the entrance of the FSC. The purpose of the guide net was to orient out-migrants towards the entrance of the collector and improve collection

[3] The Swift FSC has an operation range of 100 feet in reservoir elevation change.

efficiency. The total length of the guide net is 650 feet and it is oriented nearly perpendicular to the existing FSC barrier net. The top 30 feet of the guide net is constructed from Dyneema© with 3/32-inch mesh gap and the lower 30 feet is constructed from polyester with a 1/4-inch mesh gap for a total net depth of 60 feet. The net extends approximately 30 feet inside from the entrance of the existing Net Transition Structure (NTS) to prevent fish from easily swimming back out the opposite side of the FSC.

The FSC was operated 24-hours a day through 2016 except during periods when it was necessary to shut the facility down due to power outages, facility modification, or scheduled maintenance (Table 2.1-1).

**Table 2.1-1. List of FSC outages that occurred in 2016.**

| Outage Duration | Purpose |
|---|---|
| January 1st- January 6th | Heavy Debris Loading |
| March 3rd- March 16th | Guide Net Installation |
| July 12th- October 12th | Annual Summer Maintenance |
| December 6th- December 20th | Snow loading/unsafe operating conditions |

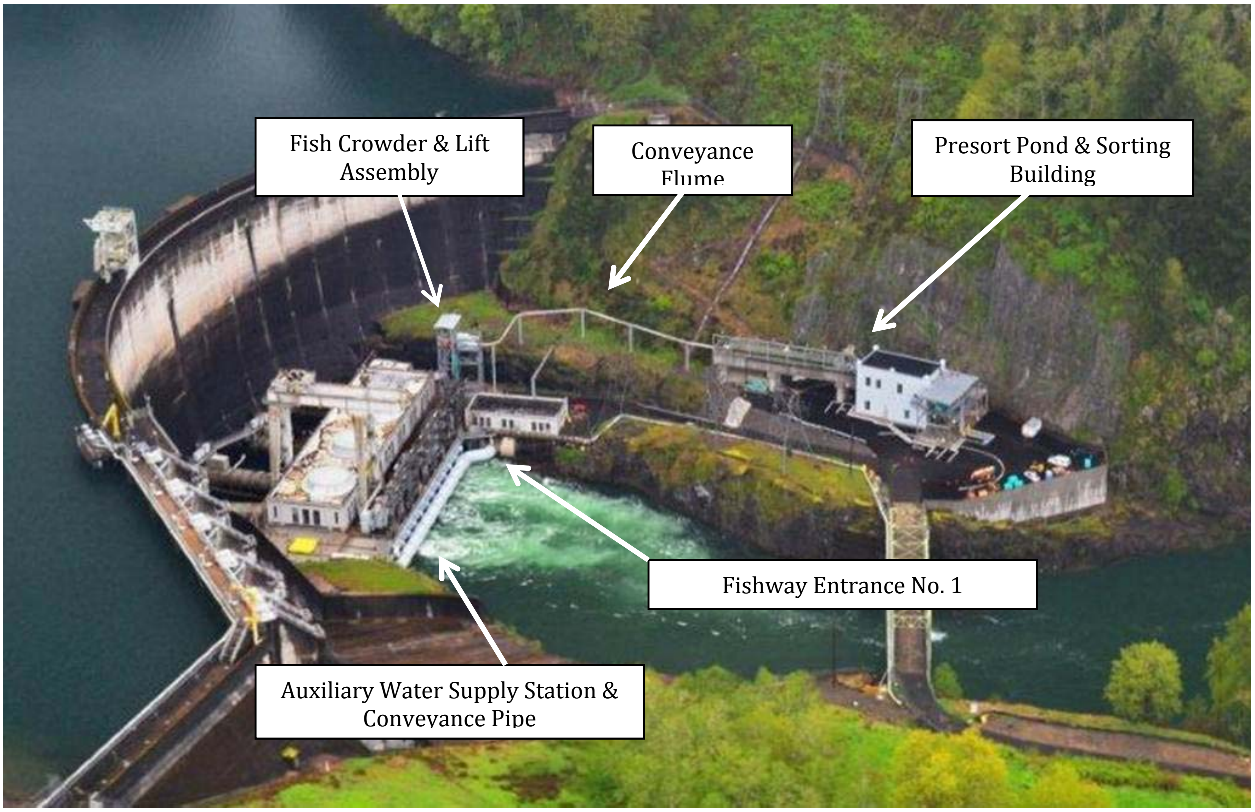



**Figure 2.2-1: Merwin Sorting Facility.**

## 2.2 Merwin Upstream Collection Facility

The new upstream collection and transport facility (Figure 2.2-1) at Merwin Dam was considered substantially complete in April 2014. The intent of the modifications made to the existing collection facility at Merwin Dam were to provide safe, timely, and effective passage of adult salmonids being transported upstream.

The new facility is designed to be constructed in phases, offering the ability to incrementally improve fish passage performance (if needed) in the future to meet biological performance goals. Depending on the biological monitoring of the facility's performance (which began spring 2015), there are up to four additional phases that will increase flow into the fishway attraction pools, and add a second fishway with additional attraction flow, if necessary (per the Lewis River Settlement Agreement Section 4.1.6.).

Phase I represents the initial construction, consisting of four major features (Figure 2.2-1):

- Auxiliary Water Supply Pump Station and Conveyance Pipe
- Fishway Entrance Number 1
- Lift and Conveyance System

- Sorting Facility

The auxiliary water supply (AWS) system provides pumped water from the tailrace to the fishway entrance pools to attract fish from the tailrace. This system uses hydraulic turbines to power attraction water pumps. Tailrace water is utilized (as opposed to reservoir water) to allow generation with the attraction flow with the high head dam prior to the water's use in the fishway. The AWS system also includes a 108-inch pipeline and conveyance conduits to deliver the water from the tailrace to the lower fishway entrance pools (Pool 1-1). The AWS system has a flow capacity of 400 cfs attraction flow (Phase 1) with the capacity of increasing flows to 600 cfs (Phase 2) if needed.

The entrance of Fishway 1 is located in the tailrace of Merwin Dam adjacent to the discharge of Turbine Unit 1 in the south corner of the powerhouse. The entrance pool (Pool 1-1) contains flow diffusers that introduce the AWS attraction water flow along the Pool 1-1 walls. The diffusers are made of construction pickets with 7/8-inch clear spacing, with baffle panels mounted immediately upstream of the diffusers to dissipate energy and provide uniform flow across the diffusers. Upstream of the lower entrance pool (Pool 1-1) are a series of ladder steps. The ladder has two intermediate pools (Pool 1-2 and Pool 1-3) leading to a loading pool (Pool 1-4). The fish ladder is designed to operate at 30 cfs, and is a "vertical slot" style fish ladder. Water is supplied from hatchery return line (HR) (~11 cfs) and the ladder water supply (LWS) system (~19 cfs). The vertical slots allow the pool levels to self-regulate the water surface elevations. Depending on tailwater elevation, the designed water elevation changes between pools ranges from 0.25 to 1.0 foot.

To prevent fish from returning to the tailrace once they have entered the lower fish ladder, a verticle fyke was installed on the upstream side of the Pool 1-2 weir in November 2016. The "V" style fyke was construcutred with one (1) inch stainless steel bars with a spacing of two (2) inch on center and has an exit slot width of six (6) inches.

The loading pool (Pool 1-4) is the last in the fishway, and contains the fish crowder which automatically loads fish into the hopper of the lift and conveyance system. The lift and conveyance system then transports fish from the fish ladder over to the sorting building. Fish are transported from the top of the elevator shaft to the pre-sort pond by the 16-inch diameter conveyance flume (Figure 2.2-2). Fish are held in the Pre-sort Pond until they are sorted by biologists on a daily basis.

All fish sorting is preformed manually on the sorting table located within the sorting building. Fish are moved from the Pre-sort Pond into the sorting building via a false weir and crowder system. An electro-anesthseia (EA) system temporarily anesthetize the fish to allow easier handling by staff, and to reduce the stress of handling on the fish during sorting. Once sorted, fish are routed into holding tanks for transport by truck to their final destination (i.e., transported upstream, to the hatchery, or returned to the lower Lewis River).

The Merwin Fish Collection Facility was operated 24-hours a day through 2016 except during periods when it was necessary to shut the facility down due to facility modifications, scheduled maintenance, or repairs (Table 2.2-1).

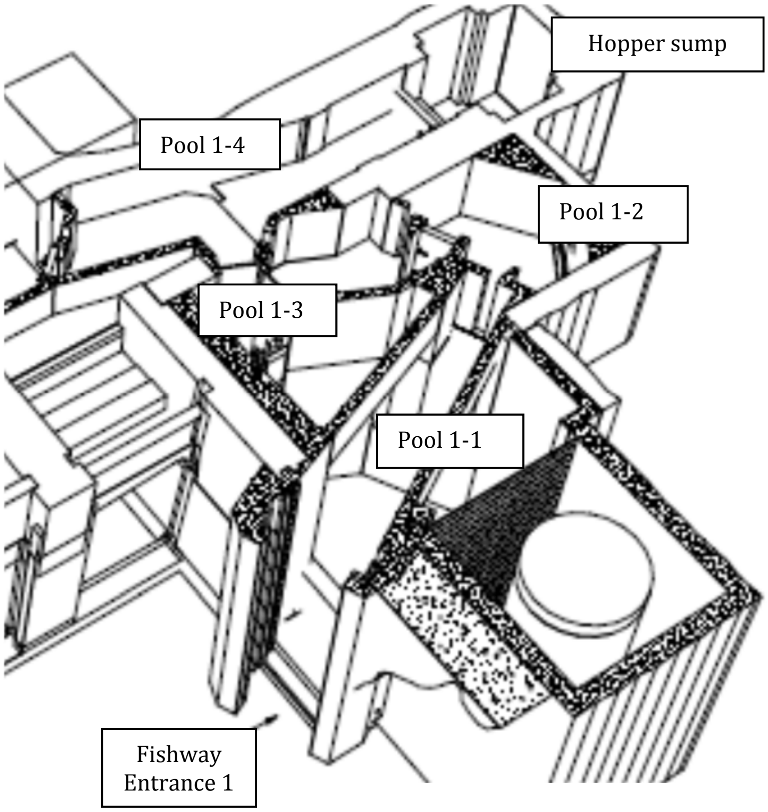



**Figure 2.2-2: Merwin Sorting Facility ladder entrance and pool configuration.**

**Table 2.2-1. A list of scheduled outages at the Merwin Fish Sorting Facility in 2015. [a] The fish ladder and fyke remained operational - only the fish lift and crowder assembly was not operated.**

| Outage Duration | Purpose |
|---|---|
| March 10th-March 13th | Repairs - lift and conveyance system |
| June 14th | Repairs- Intake Maintenance |
| January 19th | Repairs - lift and conveyance system |
| October 20th- October 24th | Repairs – Fish Crowder Cable Replacement |
| November 28th – December 12th | Repairs- Hoist Block Replacement, fyke installed |
| [a] December 17th- December 19th | Unsafe Operating Conditions Due to Freezing Temperatures |

# 3.0 DOWNSTREAM COLLECTION AND PASSAGE METRICS

## 3.1 Number of Juveniles Entering Swift Reservoir

### 3.1.1 Overview

Developing an annual estimate for total number of juveniles entering Swift Reservoir is required under section 9.2.1 of the Settlement and identified as Objective 7 of the M&E Plan. Historically, estimates of juveniles entering Swift Reservoir were estimated through screw trap operations in the mainstem of the North Fork Lewis River near Eagle Cliff during the spring outmigration period from approximately mid-March through the end of June each year. However, historic data from the FSC indicate that a considerable amount of anadromous fishes likely migrate into Swift Reservoir during periods when the Eagle Cliff screw trap is not in operation (Fall – late Winter) and that these historical estimates also do not include fish that enter Swift Reservoir from immediate tributaries to the reservoir (e.g. Drift Creek).

The revised M&E Plan addressed this issue by breaking Objective 7 into two separate parts. The first part (Objective 7 Task 7.1) estimates the timing and number of juveniles entering Swift Reservoir from the Upper North Fork Lewis River subbasin through traditional screw trapping operations near Eagle Cliff during the traditional spring migration period (March – June). Because non-sample periods and reservoir tributaries were not accounted for in this analysis, this information was to sevre as an annual index that could be compared over the same general time period among years. The second part (Objective 7 Task 7.2) estimates the total number of juveniles entering Swift Reservoir in a given year from annual PIT tag data collected at the Swift Reservior FSC.

*Objective 7 Task 7.1:*

Following the M&E Plan, monthly estimates of the total juvenile out-migration by species during the trapping season were to be calculated using the following formula for use of a single partial trap described in Volkhardt et al. (2007), in which the estimated number of unmarked fish migrating during discrete sample period $i$ ($\hat{U}$), weekly or monthly, is dependent on actual recapture rates observed:

$$\hat{U}_i = \frac{u_i(M_i+1)}{m_i+1} \quad \textbf{Equation 3.1-1}$$

Where:

$u_i$ = Number of unmarked fish captured during discrete period $i$
$M_i$ = Number of fish marked and released during period $i$
$m_i$ = Number of marked fish recaptured during period $i$

Discrete sample period variance:

$$V(\hat{U}_i) = \frac{(M_i+1)(u_i+m_i+1)(M_i-m_i)u_i}{(m_i+1)^2(m_i+2)}$$ **Equation 3.1-2**

- Monthly estimates of juvenile migration were to be combined to calculate the total number of juveniles migrating downstream during the monitoring period using the following formula:

$$\hat{U} = \sum_{i=1}^{n} \hat{U}_i$$ **Equation 3.1-3**

Entire monitoring period variance:

$$V(\hat{U}) = \sum_{i=1}^{n} V(\hat{U}_i)$$ **Equation 3.1-4**

95% Confidence Interval:

$$\hat{U} \pm 1.96\sqrt{V(\hat{U})}$$ **Equation 3.1-5**

- In addition, total season variance and confidence intervals will also be estimated using bootstrap methodology for each focal fish species total estimate (Thedinga et al. 1994).

*Objective 7 Task 7.2:*

Utilizing PIT tag records from the FSC, PIT tagged fish used to estimate the Eagle Cliff screw trap efficiency will also be used to estimate the joint probability of focal fishes that survive passage through Swift Reservoir and are captured by the FSC (ODS Section 3.7). This information can also be used to estimate, using mark-recapture, the total number of juvenile migrants in Swift Reservoir.

Recent hydroacoustic tag re-capture information has shown reservoir hold-over/rearing from one year to the next (Reynolds et.al 2015; Caldwel; et.al 2017). Comparing size class of fish captured at the screw trap to those at the FSC, in addition to assessment of long-term mark-recapture data may be used to parse yearly estimates of total fish (by species) entering the reservoir by size/year class as the long-term mark-recapture data set is developed. For 2016, yearly parsing between fish brood years was not done as more long term data is needed. Instead fish captured at the FSC of size classes too small to receive a PIT tag were not included in the estimate (i.e. they were not included in variable $u_i$ in the description below).

Estimated number of juvenile fish entering Swift Reservoir during the entire migration period will be calculated using Equation 3.1-1 above where:

$u_i$ = Total estimate of unmarked fish captured during the monitoring period at the FSC derived from equation 3.2-1 in Section 3.2;

$M_i$ = Number of fish marked and released during the monitoring period from the screw trap;

$m_i$ = Number of marked fish recaptured during the monitoring period at the FSC.

Discrete sample period variance will be calculated using bootstrap methodology (Thedinga et al. 1994). The 95% confidence interval will be calculated using Equation 3.1-5 above.

### 3.1.2 Results/Discussion

*Objective 7 Task 7.1:*

Field crews operated the Eagle Cliff 8-foot diameter rotary screw trap (trap) from March 24 to June 30, 2016, and checked the trap on a daily basis. The trap was turned off (cone raised) due to heavy debris loads for a 48-hour period from June 9 to 11, 2016; estimates of the number of fish that may have passed the trap during this time period were not made.

The total numbers of fish by species captured during the monitoring period are summarized in Table 3.1-1. Overall, out-migrating salmonids collected at the screw trap ranged in size from less than 60 mm to slightly greater than 400 mm in length (Figure 3.1-1). Juevnile coho were generally smaller with only about 10% of the captured individuals being larger than 150 mm. In contrast, more than 50% of the cutthroat and rainbow (steelhead) trout collected were greater than 150 mm in length. A total of 373 coho, 2 Chinook, 121 rainbow/steelhead, and 33 cutthroat were marked and released upstream of the trap (as fish were available from trap captures) to estimate trap efficiency via mark-recapture (Table 3.1-2). Fish were marked with a PIT-tag, alcian blue tattoo, or upper caudal fin clip. Only fish great than 60 mm fork length (FL) were used for mark-recapture efficiency tests. Due to the overall low number of fish available for marking and low recapture rates; all species efficiency tests were combined to generate weekly trap efficiency estimates (Table 3.1-3). Capture timing of juvenile salmonids smolts tended to peak during the beginning of May while juveniles below 60 mm in length peaked during the end of May (Figure 3.1-2). Fish capture timing was calculated by making estimates of total fish passing the trap on a weekly basis using the adjusted weekly trap efficiency summarized in Table 3.1-3. Total estimates of fish passing the trap during the trapping period and 95% confidence intervals were generated using the Bootstrap Methodology (Thidenga et al. 1994). (*The sum of discrete interval method of calculating total fish estimates described by Volkhardt et al. (2007) (as prescribed in the M&E Plan) could not be used due to the low number of weekly recaptures)*. In total 4,485 coho, 100 spring Chinook, 1,976 steelhead, and 623 cutthroat were estimated to pass the trap during trapping operations (Table 3.1-4). These estimates should only be viewed as an index of the total fish that passed the trap during the trapping period and not total species outmigration abundance.

**Table 3.1-1. Summary of Eagle Cliff trap total captures.**

| Species | Total w/ Adipose Fin Clip | Total <60 mm FL (Adipose Fin Intact) | Total ≥60 mm FL (Adipose Fin Intact) |
|---|---|---|---|
| Coho | 0 | 116 | 232 |
| Chinook | 0 | 0 | 3 |
| Rainbow/Steelhead | 12 | 3 | 144 |
| Cutthroat | 0 | 0 | 42 |
| Bull Trout | 0 | 0 | 4 |
| **Species** | **Total** | | |
| Mountain Whitefish | 2 | | |
| Sculpin | 63 | | |
| Largescale Sucker | 36 | | |
| Unidentified Salmonid Fry | 3 | | |

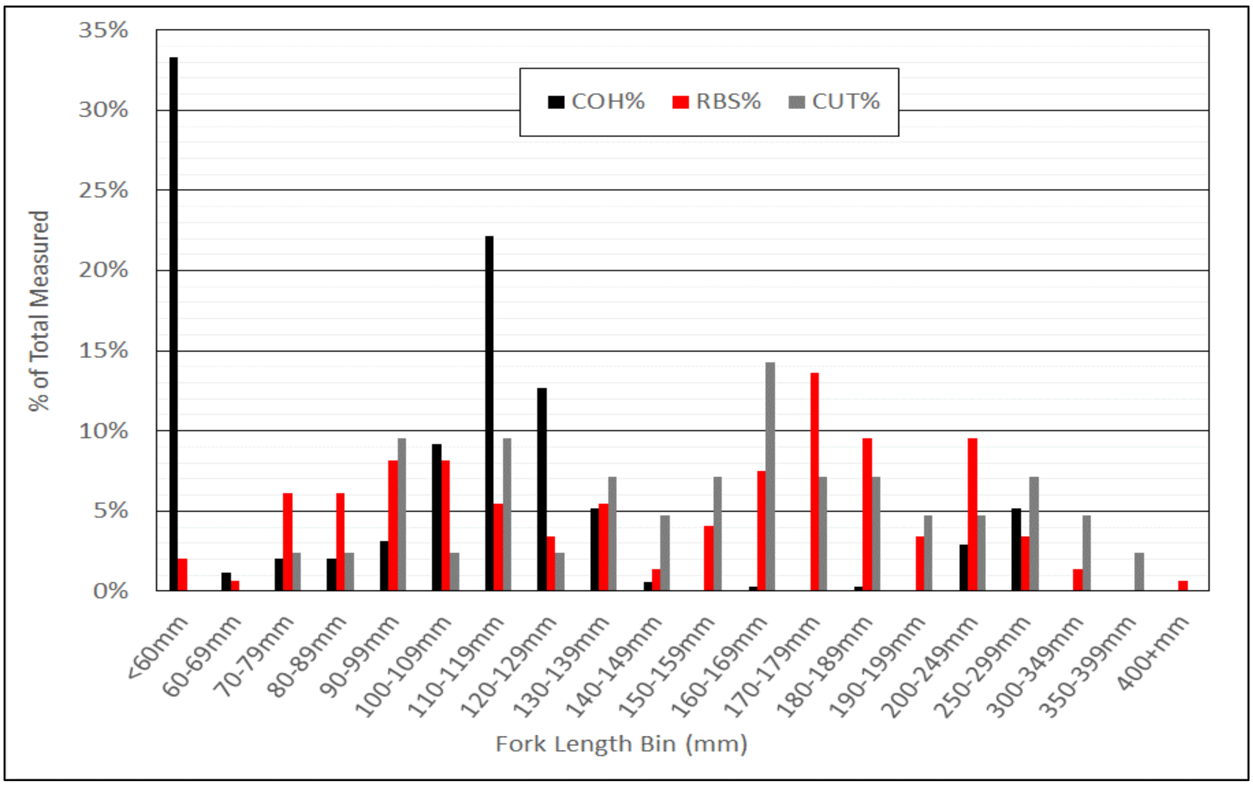



**Figure 3.1-1. Length frequency distribution (coho, rainbow/steelhead, cutthroat with adipose fin intact).**

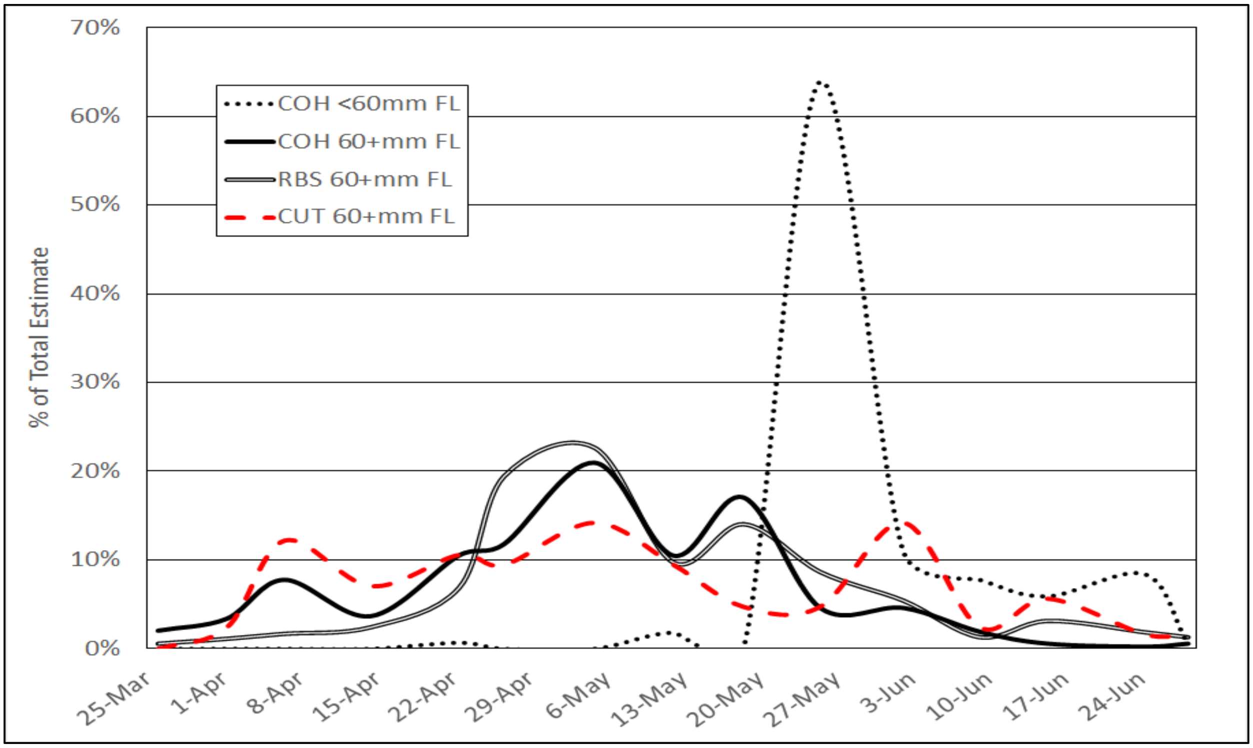



**Figure 3.1-2. Species migration timing based on total weekly estimates (adipose fin intact).**

**Table 3.1-2. Summary of mark-recapture tests of trap efficiency by species. [a] Includes 199 coho PIT-tagged and released upstream from FSC captures.**

| Species | Total Marked & Released Upstream ≥60 mm FL | Total Recaptured | Trap Efficiency |
|---|---|---|---|
| Coho | 373 [a] | 13 | 0.035 |
| Chinook | 2 | 0 | NA |
| Rainbow/ Steelhead | 121 | 3 | 0.025 |
| Cutthroat | 33 | 5 | 0.152 |
| All Salmonids | 529 | 21 | 0.040 |

**Table 3.1-3. Summary of weekly mark-recapture tests of trap efficiency.**

| Week | Total Caught ≥60 mm FL | Total Marked & Released Upstream ≥60 mm FL | Total Recaptured | Trap Efficiency | Average Weekly Flow (cfs)[e] | Adjusted Efficiency Based on Flow |
|---|---|---|---|---|---|---|
| 1 | 7 | 7 | 0 | NA | 2,012 | 0.043[a] |
| 2 | 13 | 12 | 0 | NA | 1,826 | 0.043[a] |
| 3 | 32 | 7 | 0 | NA | 2,239 | 0.043[a] |
| 4 | 25 | 20 | 1 | 0.050 | 1,696 | 0.059[b] |
| 5 | 67 | 48 | 3 | 0.063 | 2,023 | 0.059[b] |
| 6 | 38 | 30 | 1 | 0.033 | 1,211 | 0.022[c] |
| 7 | 57 | 45 | 2 | 0.044 | 1,511 | 0.022[c] |
| 8 | 27 | 226 | 4 | 0.018 | 1,243 | 0.022[c] |
| 9 | 41 | 32 | 1 | 0.031 | 1,033 | 0.022[c] |
| 10 | 19 | 19 | 0 | NA | 785 | 0.022[c] |
| 11 | 17 | 13 | 0 | NA | 759 | 0.022[c] |
| 12 | 28 | 20 | 5 | 0.250 | 640 | 0.129[d] |
| 13 | 34 | 27 | 2 | 0.074 | 605 | 0.129[d] |
| 14 | 16 | 16 | 1 | 0.063 | 530 | 0.129[d] |
| 15 | 16 | 7 | 1 | 0.143 | 463 | 0.129[d] |
| **Total** | **437** | **529** | **21** | **0.040** | | |

[a]Sum of weeks 1 through 5 mark/recapture.
[b]Sum of weeks 4 through 5 mark/recapture (trap moved upstream to a more efficient location).
[c]Sum of weeks 6 through 11 mark/recapture.
[d]Sum of weeks 12 through 15 mark/recapture.
[e]USGS 14216000 Lewis River Above Muddy River Near Cougar, WA

**Table 3.1-4. Index estimates of fish (adipose fin intact and ≥60 mm FL) passing the Eagle Cliff trap by species (Bootstrap method) from March 24th to June 30th, 2016.**

| Species | Capture Efficiency Applied | Bootstrap Mean Total Estimate (March 24 – June 30, 2016) | 95% CI +/- |
|---|---|---|---|
| Coho | 0.035 | *7,164* | **4,485** |
| Chinook | 0.040 | *77* | **100** |
| Rainbow/Steelhead | 0.040 | *3,832* | **1,976** |
| Cutthroat | 0.040 | *1,104* | **623** |

*Objective 7 Task 7.2:*

All PIT tags used in the screw trap operations were also used in Task 7.2. In addition to these tags, PacifiCorp PIT tagged coho juveniles captured at the FSC and released them at the head of Swift Reservoir. A total of 686 coho, 79 steelhead, and 22 cutthroat juveniles were additionally tagged and released at the head of Swift Reservoir for analysis. Spring Chinook were not included in the estimate due to the low numbers of fish tagged (n = 2). Estimates were first developed using Equation 3.1-1 (above). These estimates differed from estimated bootstrapping means for steelhead (~ 9% underestimation discrepancy), and for cutthroat (~ 125% overestimation discrepancy) therefore bootstrapping methodology was applied to find both the mean and variances of total number steelhead and cutthroat entering Swift Reservoir during 2016. Equation 3.1-1 was used for coho as the bootstrapping mean produced nearly the same estimate. It is estimated that 189,999 coho, 14,087 steelhead, and 5,442 cutthroat juveniles entered Swift Reservoir during year 2016 (Table 3.1-5). Comparing these estimates to the number of juveniles estimated to pass Eagle Cliff during screw trapping operations in 2016 reveals that the majority of juvenile fish enter Swift Reservoir during times when the screw trap was not in operation.

**Table 3.1-5. Estimates of total fish (adipose fin intact and ≥60 mm FL) entering Swift Reservoir during 2016 by species (Bootstrap method).**

| Species | Tags Released | Tags Recaptured at FSC | Capture Efficiency Applied | Total untagged fish captured at FSC | Bootstrap Mean Total Estimate | 95% CI +/- |
|---|---|---|---|---|---|---|
| Coho | 686 | 214 | 0.312 | 59,461 | *189,999* | **22,316** |
| Chinook | 2 | 0 | NA | 3,787 | *NA* | **NA** |
| Steelhead | 79 | 12 | 0.152 | 2,091 | *14,087* | **8,820** |
| Cutthroat | 22 | 1 | 0.045 | 1,049 | *5,442* | **9,877** |

## 3.2 Fish Numbers Collected at the FSC

### 3.2.1 Overview

Section 9.2.1(j) of the Settlement Agreement requires PacifiCorp to enumerate the number of salmonids collected at FSC ($FSC_{COL}$) by species and life-stage. This requirement is identified as Objective 6 in the M&E Plan. The M&E Plan originally stated that the number of juvenile fish entering the FSC would be calculated through both subsampling and by automatic fish counters. During development of the M&E Plan the accuracy of the automatic fish counters were unknown, thus conducting both methods of enumeration was recommended initially. However, during the operating years of 2013 and 2014, many tests and calibrations took place. From this work, it was ultimately determined that the scanners were unreliable, and falsely assigned debris and turbulence as fish. Because the automatic fish counters were shown to be unreliable for long term daily operation, estimating total number of fish collected at the FSC was achieved through subsampling counts as described in Section 2.6.1 of the M&E Plan; the key assumption inherent in the methodology is that the subsampled fish are representative of the general population.

*SUBSAMPLING COUNTS*

Diversion gates on the FSC allow for smolts to be diverted into either a subsample tank or a general population tank. The diversion gates operate on a time-driven interval within a ten minute time frame (i.e., during a 10 percent sample period the diversion gate would operate one minute out of every ten minute cycle). The intent is that during periods of low migration the sampling rate is set to 100% and all fish collected are processed. When capture rates increase (i.e., during peak outmigration), only a portion of fish are sampled and the rest are diverted to the general population tanks. As described in the M&E Plan, the daily subsample totals, as well as the associated variance estimators, could then be calculated by:

Total Number of Fish (subsampling period):

$$T = N\bar{y} = \frac{N}{n}\sum_{i=1}^{n} y_i \quad \textbf{Equation 3.2 - 1}$$

With associated variance estimator:

$$\boldsymbol{s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(y_i - \bar{y})^2} \quad \textbf{Equation 3.2 - 2}$$

And 95% Confidence Interval:

$$O + T \pm t_{(0.025,n-1)}\sqrt{\frac{N(N-n)s^2}{n}} \quad \textbf{Equation 3.2 - 3}$$

Where,

$T$ = total number of fish during the subsampling period
$O$ = total number of fish during 100% enumeration period
$r$ = subsampling rate
$n$ = number of sampling periods (days sampled)
$N$ = n/r (sampling intensity)
$y_i$ = discrete daily fish count
$\overline{y}$ = average number of fish counted per day
$s^2$ is the sample variance
$t$ is the t-statistic for n-1 degrees of freedom and α/2

Daily fish collection numbers remained manageable throughout most of 2016, and sample rates were set to 100% for a majority of the year. Subsampling only occurred on 56 days of operation, primarily between April 23 and June 17th. For this period, the equations described above were used to derive the total number of fish collected on a given day, as well as the associated variance estimator.

### 3.2.2 Results/Discussion

A total of 73,539 (95% CI range: 62,878 to 84,200) salmonids were captured by the FSC in 2016 (Table 3.2-1). Of these fish, approximately 68,175 were transported and released downstream of Merwin Dam (Table 3.2-2). Juvenile coho accounted for the highest proportion of the overall estimated catch (82.9%), followed by spring Chinook (5.2%), steelhead (3.1%) and coastal cutthroat trout (1.4%). A total 3,458 hatchery rainbow trout and 40 bull trout were also collected in 2016 and returned to the reservoir. Approximately 1,713 hatchery rainbow trout were passed downstream of Merwin Dam during the subsample collection period (May-June).

**Table 3.2-1: Estimated monthly and annual totals of all species collected at the FSC.**

| Month | Coho | | | | Spring Chinook | | | Steelhead | | | | | Cutthroat | | | Bull Trout | Rainbow Trout | Total Trapped |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fry | Parr | Smolt | Adult | Fry | Parr | Smolt | Fry | Parr | Smolt | Adult | Kelt | Fry | < 13 in | > 13 in | | | |
| January | 1 | 3,435 | 2,557 | 3 | 0 | 256 | 1,381 | 0 | 5 | 37 | 0 | 0 | 2 | 79 | 8 | 13 | 113 | 7,790 |
| February | 0 | 4,693 | 1,907 | 0 | 0 | 308 | 750 | 0 | 10 | 35 | 0 | 0 | 0 | 78 | 5 | 4 | 150 | 7,940 |
| March | 0 | 965 | 1,504 | 0 | 0 | 64 | 200 | 0 | 2 | 26 | 8 | 0 | 0 | 62 | 1 | 6 | 593 | 3,431 |
| April | 223 | 1,377 | 8,904 | 0 | 0 | 63 | 219 | 1 | 39 | 459 | 18 | 30 | 2 | 164 | 7 | 5 | 1,975 | 13,486 |
| May | 290 | 163 | 23,346 | 0 | 0 | 0 | 233 | 0 | 2 | 1,390 | 10 | 22 | 1 | 546 | 4 | 8 | 1,390 | 27,405 |
| June | 2 | 87 | 10,029 | 0 | 0 | 1 | 74 | 1 | 5 | 125 | 0 | 13 | 0 | 81 | 8 | 3 | 813 | 11,,240 |
| July | 201 | 74 | 65 | 0 | 0 | 0 | 0 | 25 | 1 | 4 | 0 | 0 | 0 | 4 | 0 | 0 | 136 | 510 |
| August | | | | | | | | | | | | | | | | | | |
| September | | | | | | | | | | | | | | | | | | |
| October | 28 | 142 | 121 | 40 | 2 | 24 | 48 | 3 | 6 | 3 | 0 | 1 | 16 | 2 | 0 | 0 | 3 | 439 |
| November | 46 | 309 | 320 | 46 | 3 | 47 | 163 | 1 | 3 | 11 | 0 | 0 | 10 | 15 | 0 | 0 | 9 | 983 |
| December | 45 | 62 | 80 | 45 | 1 | 10 | 46 | 1 | 1 | 5 | 0 | 0 | 1 | 5 | 0 | 1 | 12 | 315 |
| **Annual Total** | **836** | **11,307** | **48,833** | **134** | **6** | **673** | **3114** | **32** | **74** | **2095** | **36** | **66** | **32** | **1036** | **33** | **40** | **5,194** | **73,539** |

**Table 3.2-2: Estimated annual totals of species transported downstream.**

| Coho | | | | Spring Chinook | | | | Steelhead | | | | | Cutthroat | | | Bulltrout | Rainbow Trout | Target Species Downstream |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Fry** | **Parr** | **Smolt** | **Adult** | **Fry** | **Parr** | **Smolt** | **Adult** | **Fry** | **Parr** | **Smolt** | **Adult** | **Kelt** | **Fry** | **<13 in** | **>13 in** | **All sizes** | **All Sizes** | |
| 836 | 11,307 | 4,8833 | 0 | 6 | 673 | 3114 | 0 | 32 | 74 | 2095 | 0 | 66 | 32 | 1036 | 33 | 0 | 1,713 | 68,175 |

**Table 3.2-3: Estimated annual totals of species and life stage collected by the FSC.**

| Species/Lifestage | Estimated Number Collected | Associated Variance | Collection Range at 95% CI |
|---|---|---|---|
| Coho Fry | 836 | 0 | 836 |
| Coho Parr | 11,307 | 1013 | 10,294-12,320 |
| Coho Smolt | 48,333 | 7357 | 40,976-55,690 |
| Coho Adult | 134 | 0 | 134 |
| Chinook Fry | 6 | 0 | 6 |
| Chinook Parr | 673 | 0 | 673 |
| Chinook Smolt | 3,114 | 332 | 2,782-3,446 |
| Steelhead Fry | 32 | 0 | 32 |
| Steelhead Parr | 74 | 58 | 16-132 |
| Steelhead Smolt | 2,095 | 625 | 1,470-2,720 |
| Steelhead Adult | 36 | 0 | 36 |
| Steelhead Kelt | 66 | 0 | 66 |
| Cutthroat Fry | 32 | 0 | 32 |
| Cutthroat <13 in | 1,036 | 380 | 6,56-1,416 |
| Cutthroat >13 in | 33 | 18 | 15-51 |
| Bull Trout | 40 | 0 | 40 |
| Rainbow Trout | 5,194 | 878 | 4,316-6,072 |
| **Total** | **73,539** | **10,661** | **62,878-84,200** |

# 3.3 Juvenile Migration Timing

## 3.3.1 Overview

In accordance with section 9.2.1(a) of the Settlement Agreement, PacifiCorp is required to determine natural juvenile migration timing by tracking abundance at the FSC each year. This task was identified as Objective 8 in the M&E Plan with the assumption that run-timing is an index that applies to fish arriving at the FSC.

Following the M&E Plan, an index of juvenile migration was developed by tracking the number of fish captured each day at the FSC over time. The number of fish collected each day at the FSC ($FSC_{col}$) was calculated by equation 3.2.-1, and plotted on a daily basis.

In addition to monitoring migration timing, PacifiCorp also monitored juvenile fork lengths to describe, temporally, the size (or life-stage) of fish entering the FSC. Size distributions for coho, spring Chinook, steelhead and coastal cutthroat were calculated on a seasonal basis for the periods January – March, April – June and October – December. Size distributions were not calculated for the time period between early July through September as the FSC was off for annual maintenance.

## 3.3.2 Results/Discussion

Overall, the run timing in 2016 followed a normal spring time distribution for rivers west of the Cascade Crest and similar to previous years of operation. With the exception of spring Chinook, the peak spring out-migration period of all other juvenile salmonids generally occurred from the first of April through June. Within this time frame, 72.5% of the coho, 91.7% of the steelhead and 73.5% of the cutthroat were collected relative to the total annual catch (Figures 3.3-1 through 3.3-12). Spring Chinook demonstrated a slightly earlier peak migration period, with approximately 76.7% of the run occurring between January 1- March 31. Coho parr also exhibited a slightly earlier migration, with 80.4% of the run occurring between January 1- March 31. The late fall/early winter outmigration period that has historically accounted for a significant portion of the spring Chinook collection was much less pronounced in 2016. Coastal cutthroat followed a similar out-migration trend as coho, with the majority of fish passing in April and May along with a smaller component of fish out-migrating in the fall.

*COHO SIZE DISTRIBUTIONS*

A bimodal size distribution was observed for juvenile coho collected at the FSC throughout the year, however the mean length of each mode varied by season. Early in the year (January – March), coho fry and parr dominated the catch followed by a smaller component of larger smolts (220 – 290 mm). The bimodal size distribution was also evident in the spring (April – June), but much less pronounced. During this timeframe, the vast majority (>90%) of coho out-migrants had lengths greater than 121 mm (Figure 3.3-11). Of the coho that were collected in the late fall/early winter (October – December), the majority (68.3%) had lengths of less than 120 mm (Figure 3.3-11).

### *Spring Chinook Size Distributions*

Review of spring Chinook data captured at the FSC in 2016 reveals size class distribution patterns that positively correlate with hatchery smolt releases.  This suggests the majority of spring Chinook collected by the FSC in 2016 originated from the acclimation plants that occurred during October of 2015. Of the 3,793 spring Chinook that were captured at the FSC in 2016, over 82% had fork lengths >121 mm (Figure 3.3-12), with a mean fork length of 159.7 mm. Of the approximately 29,900 spring Chinook that were released in the ULR basin during the Fall of 2016, fewer than 350 (n=343) had been collected at the FSC by the end of December. Additionally, smaller spring Chinook (less than 120 mm) were also observed, predominately in early spring , suggesting that some natural production is occurring.  No adult spring Chinook have been introduced since 2013, which indicates that natural populations of spring Chinook residing in the reservoir are maturing in fresh water and successfully reproducing in the upper tributaries.

### *Steelhead Size Distributions*

The median fork length for steelhead in 2016 was 223 mm, with the vast majority (>82%) having fork lengths that were >150 mm. During peak migration (April – June), the mean steelhead fork length was approximately 230 mm (Figure 3.3-15).  The few steelhead that were captured during the remainder of the year displayed a variety of sizes (Figure 3.1-15).

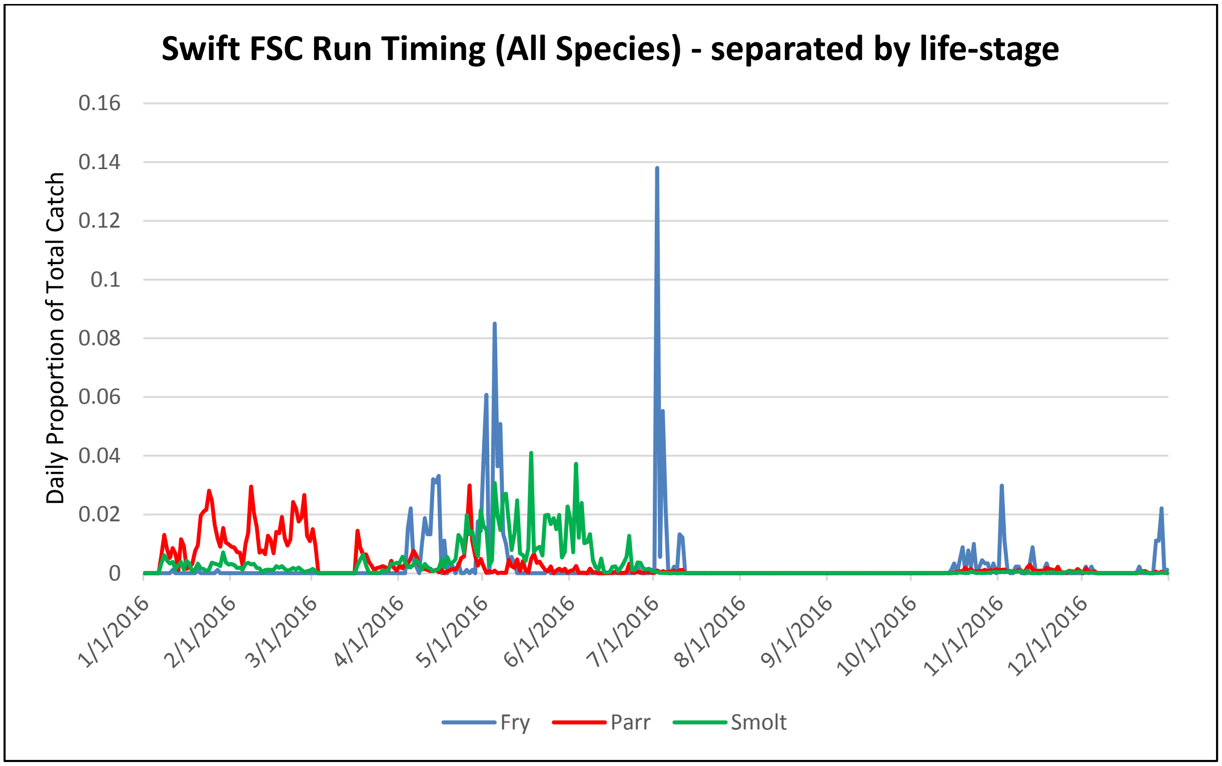



**Figure 3.3-1: Estimated daily percent of total migration among all species captured at the FSC.**

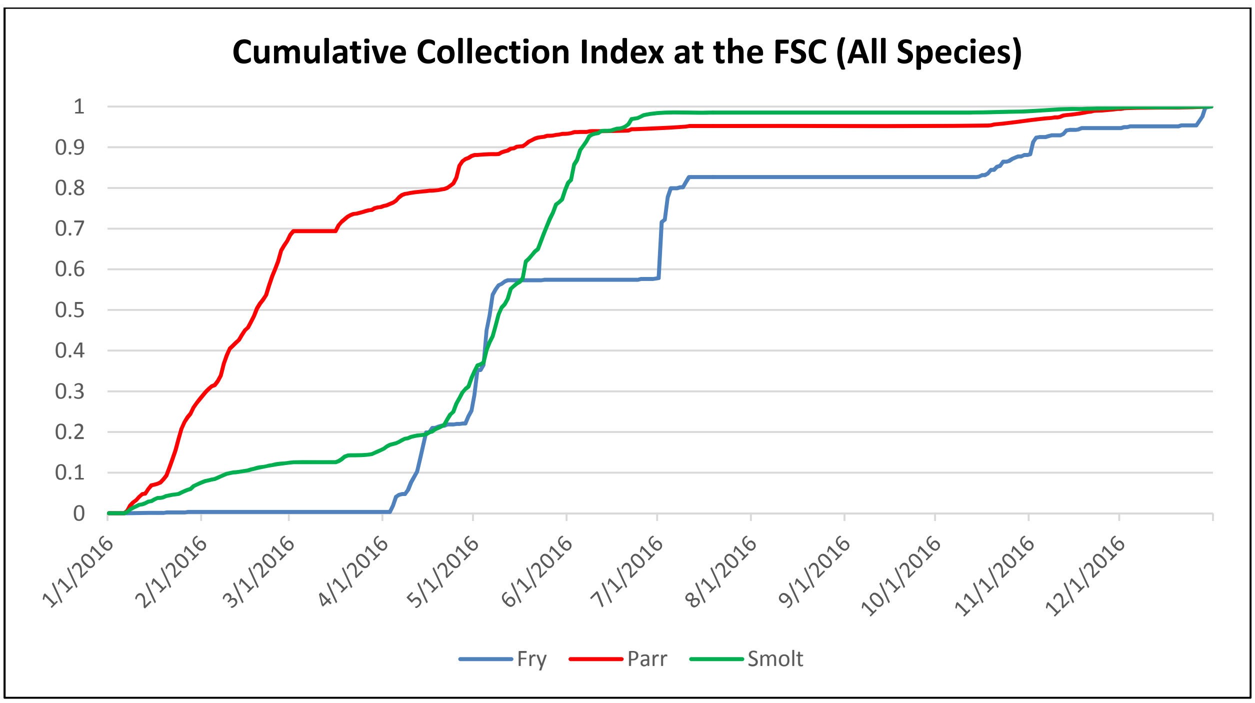



**Figure 3.3-2: Cumulative migration timing among all species of fish.**

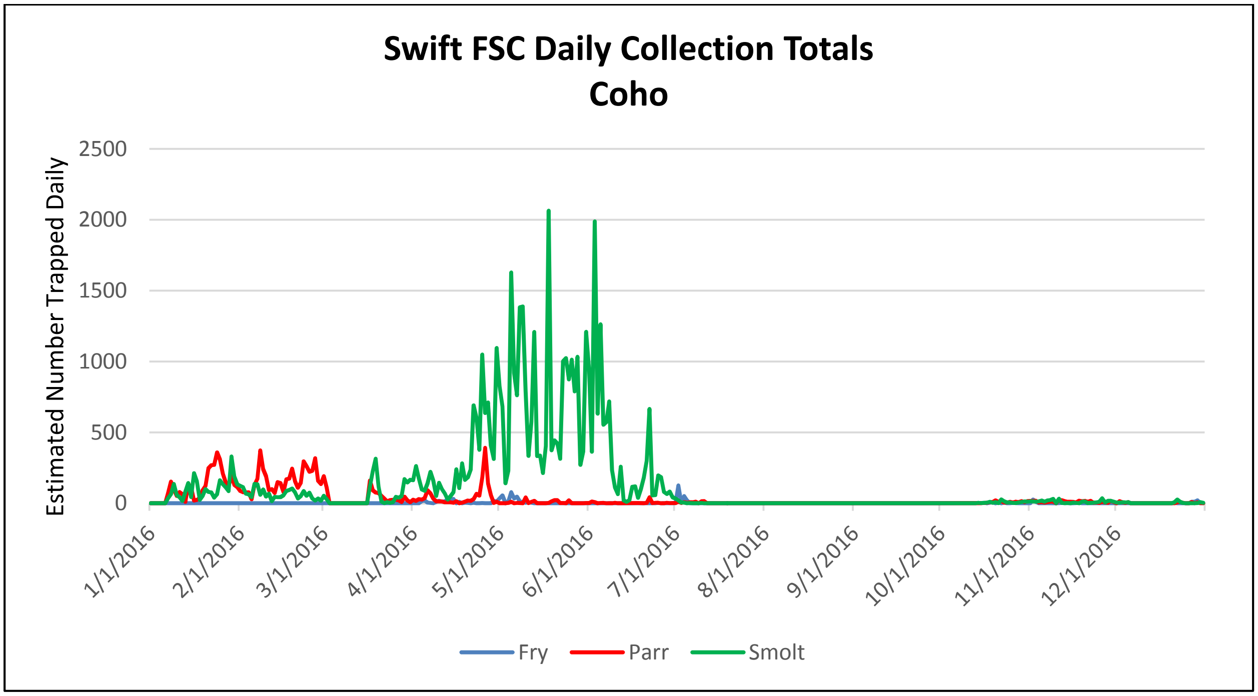



**Figure 3.3-3: Estimated daily counts of juvenile coho captured at the FSC.**

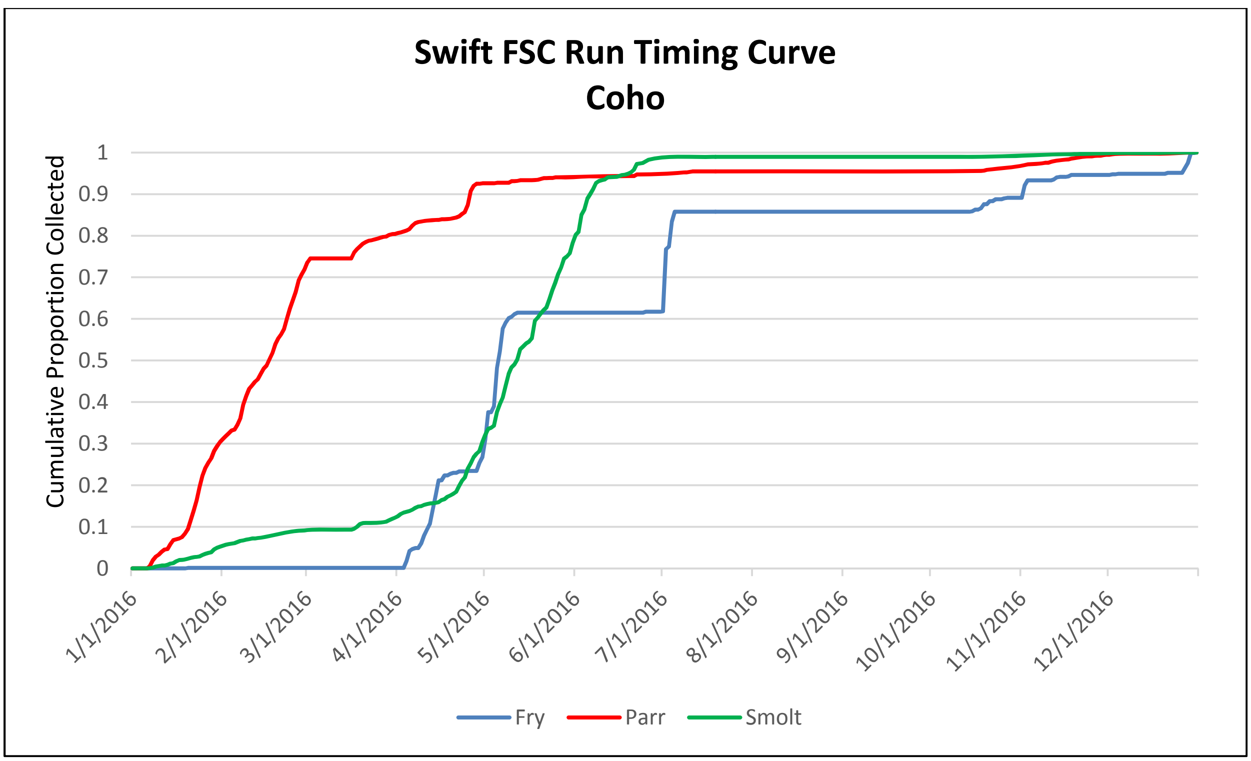



**Figure 3.3-4: Cumulative coho migration timing.**

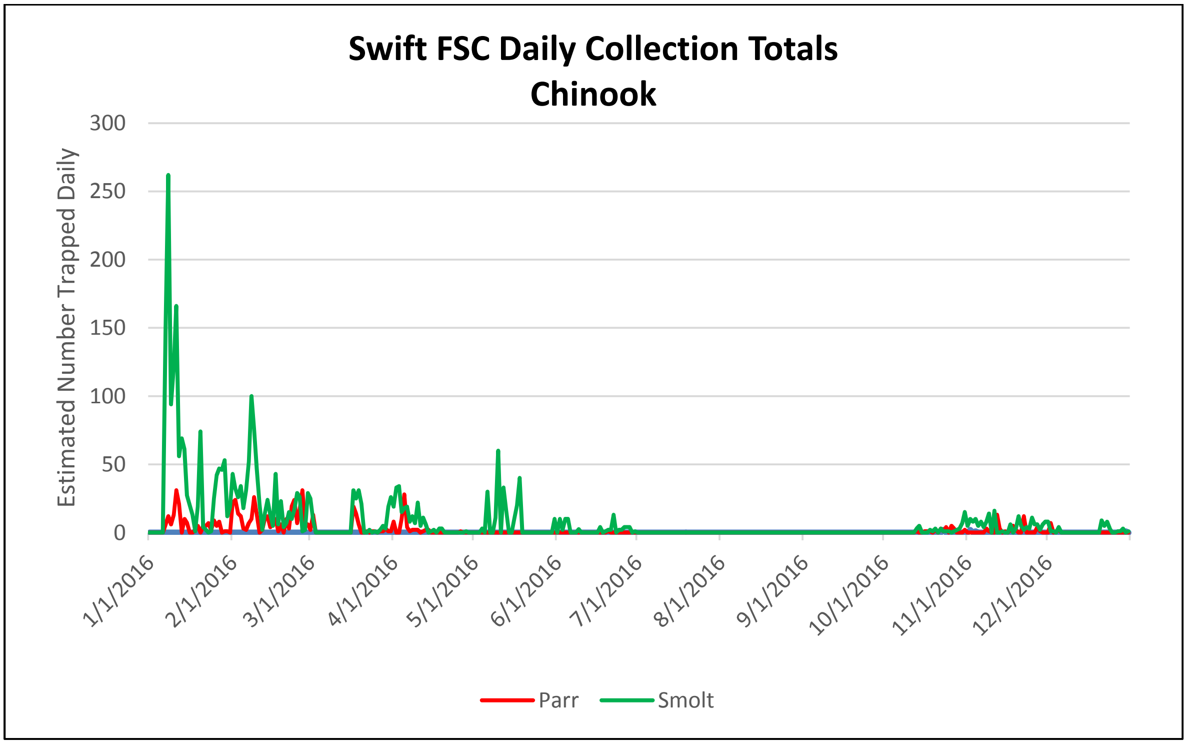



**Figure 3.3-5: Estimated daily counts of juvenile spring Chinook captured at the FSC.**

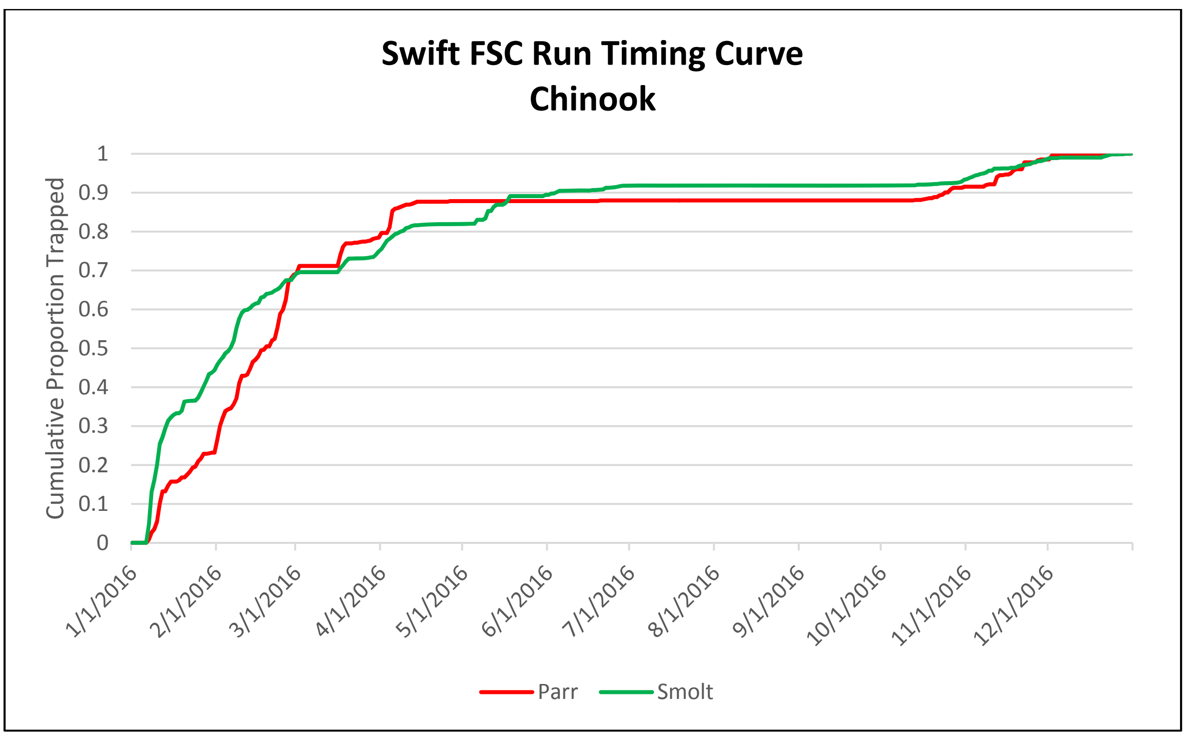



**Figure 3.3-6: Cumulative spring Chinook migration timing.**

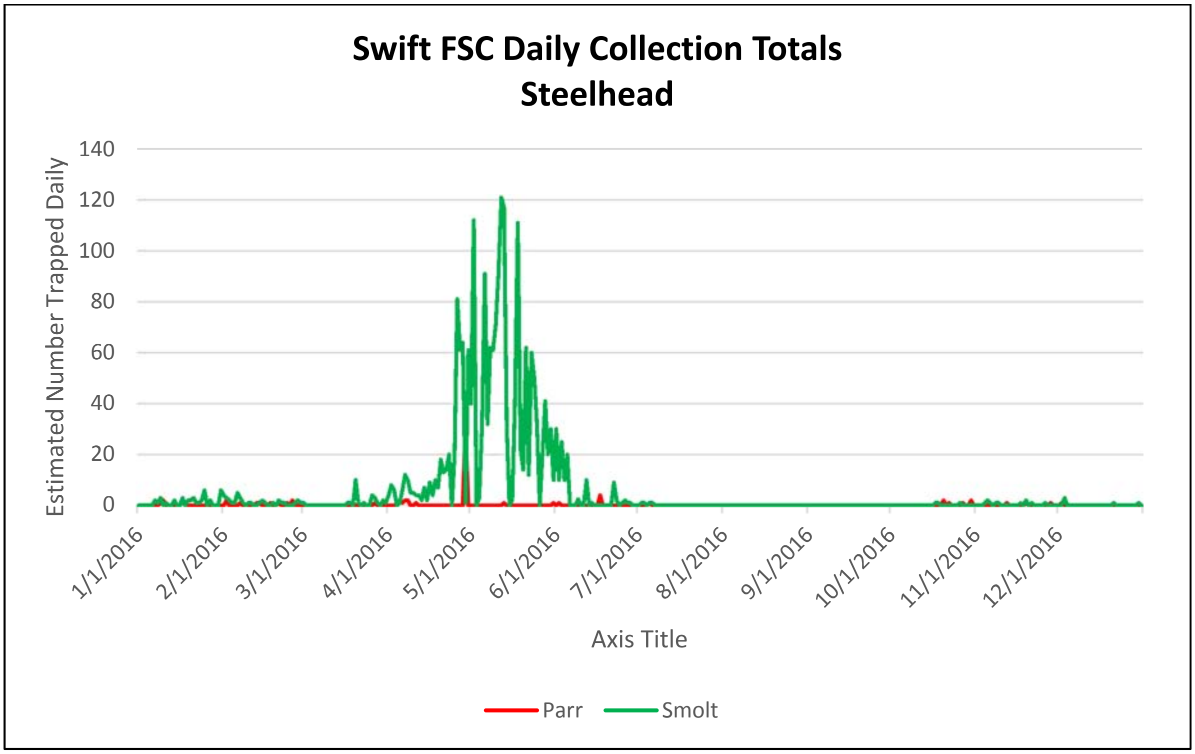



**Figure 3.3-7: Estimated daily counts of juvenile steelhead captured at the FSC.**

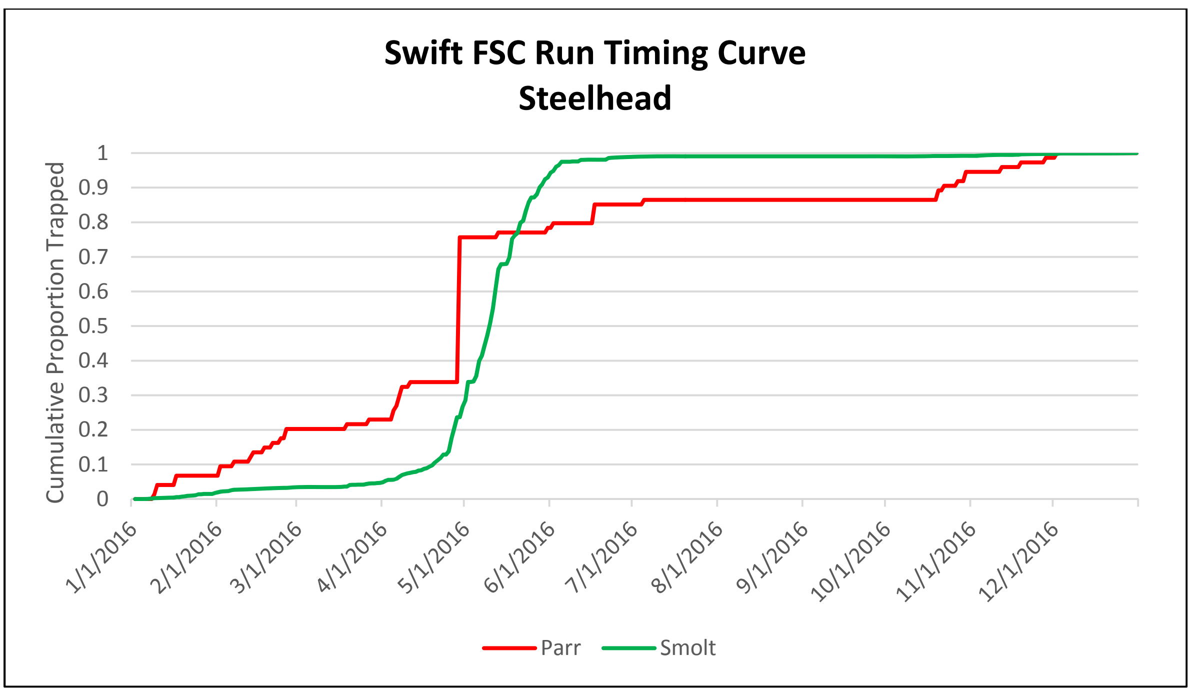



**Figure 3.3-8: Cumulative steelhead migration timing.**

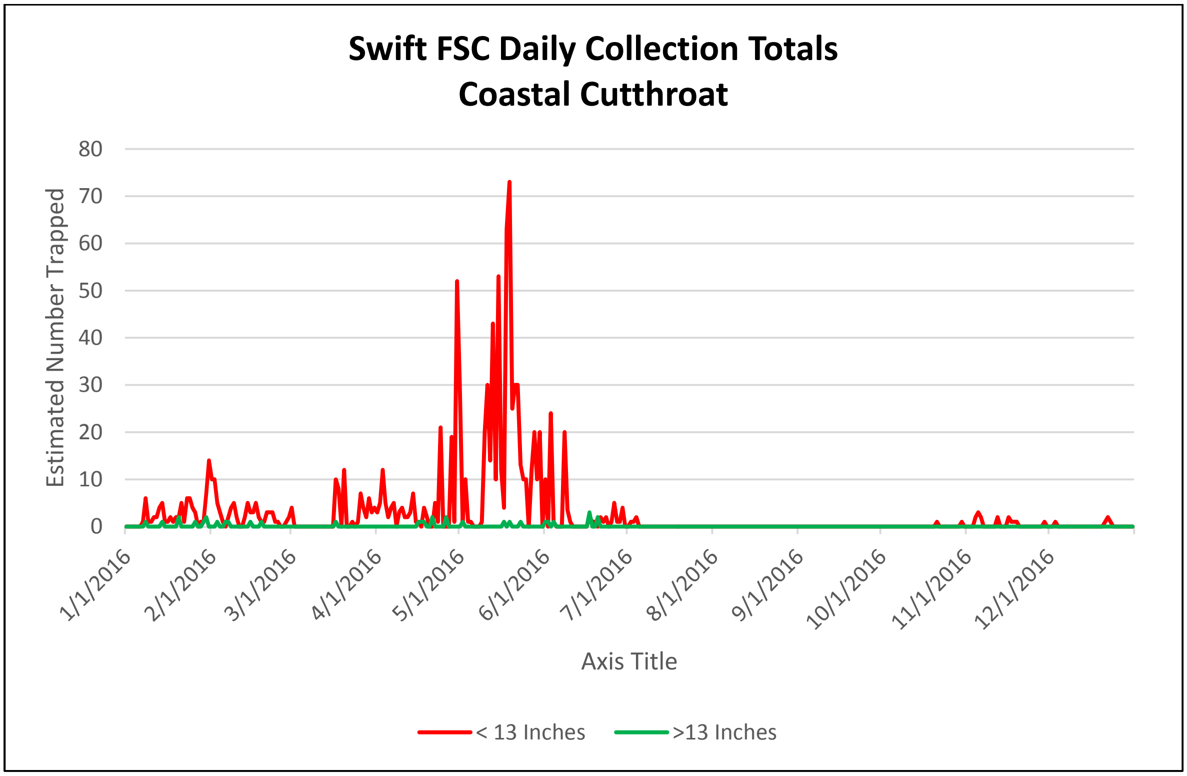



**Figure 3.3-9: Estimated daily counts of cutthroat captured at the FSC.**

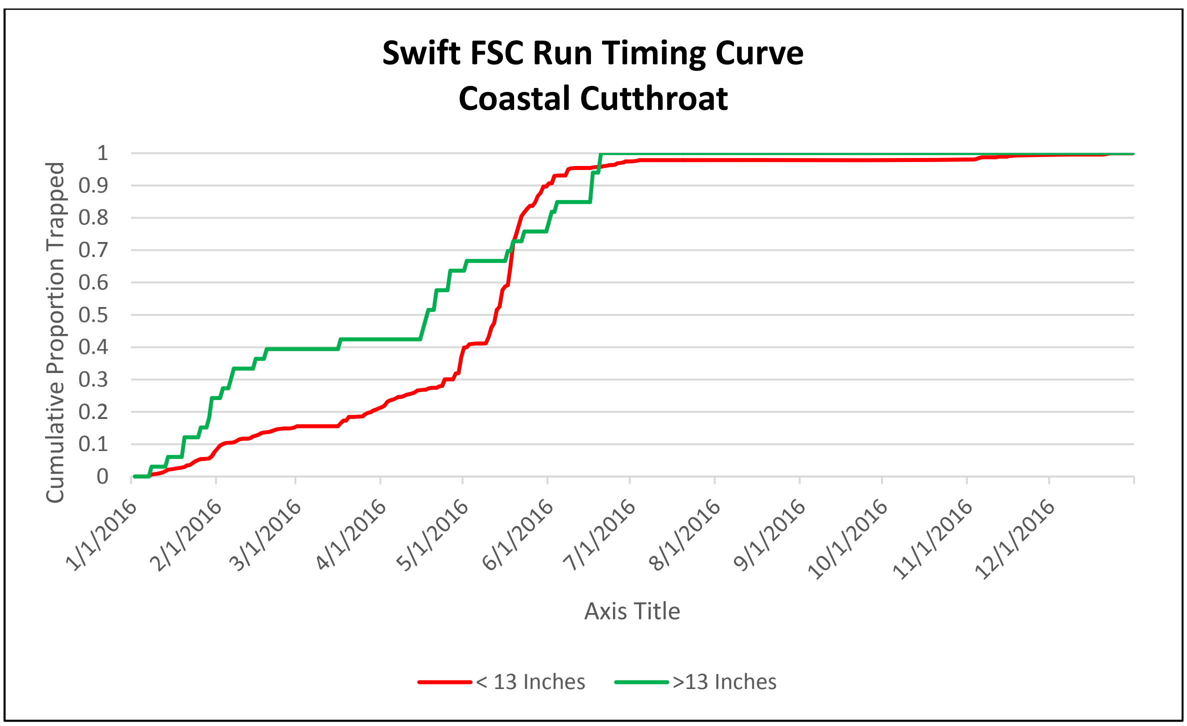
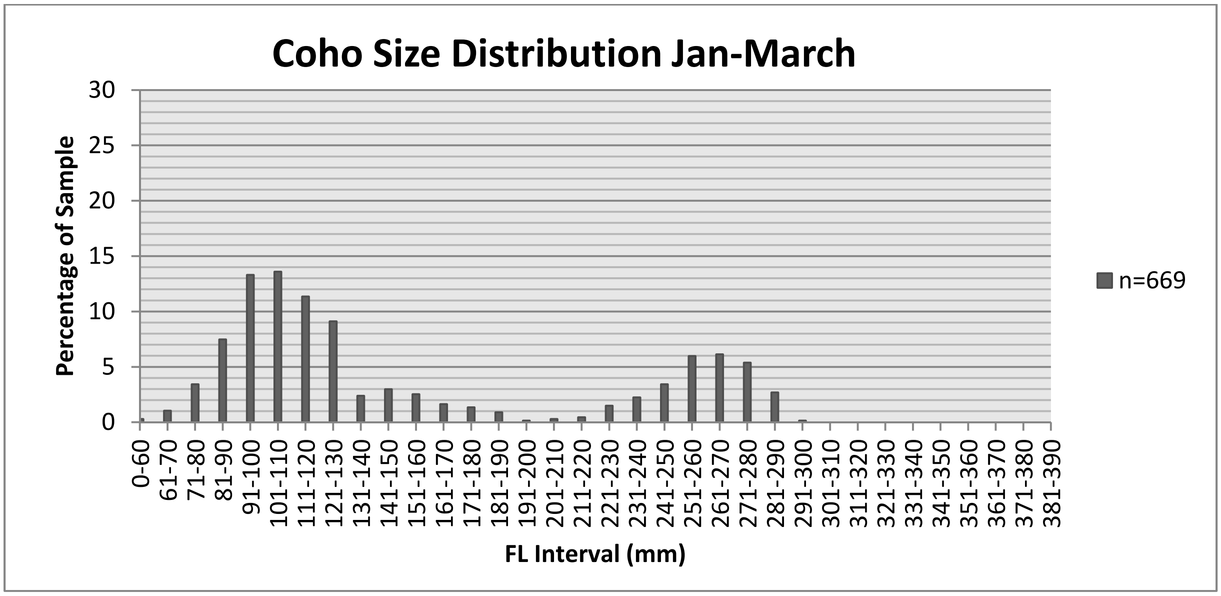



**Figure 3.3-10: Cumulative cutthroat migration timing.**



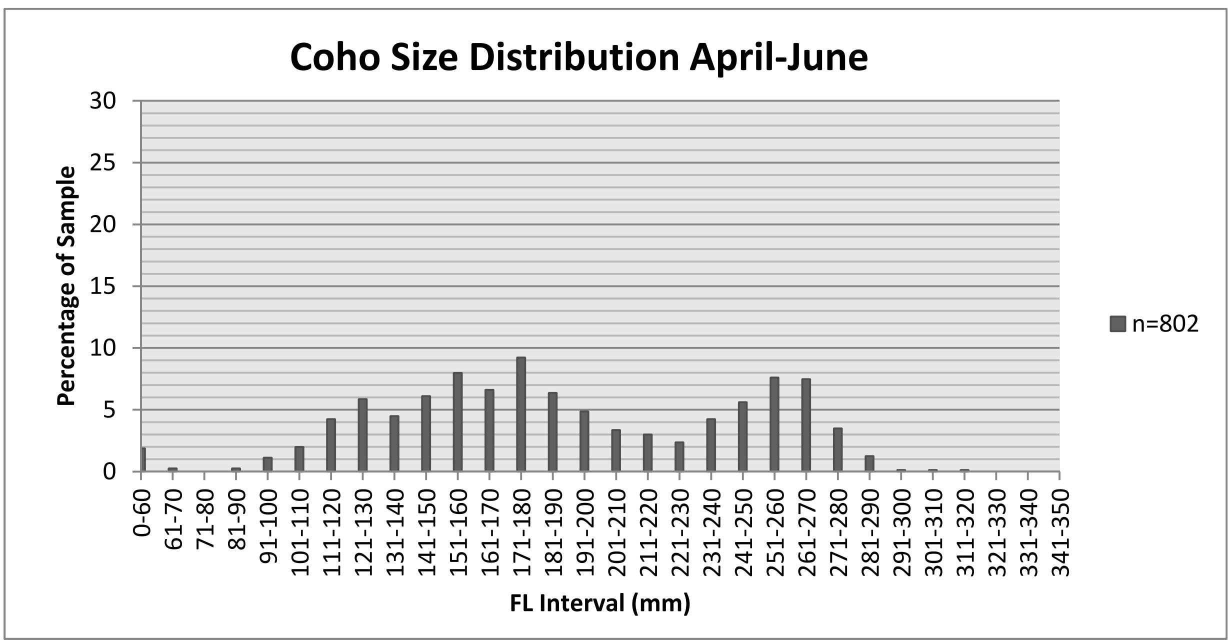
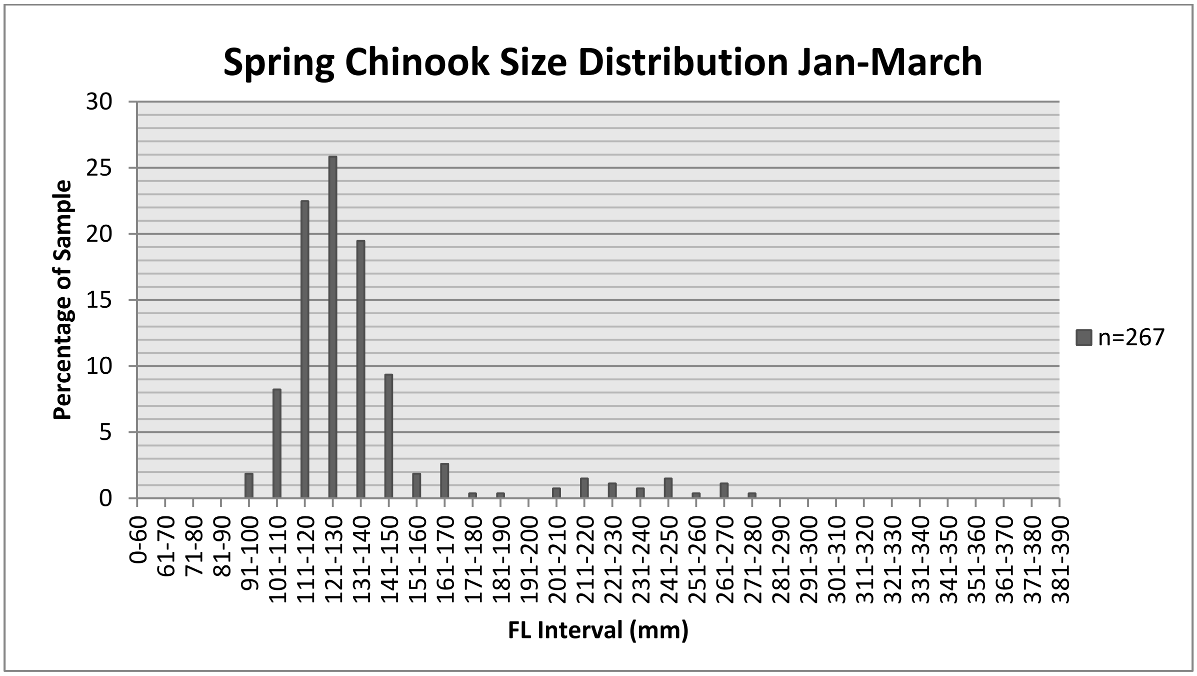




**Figure 3.3-11: Size distribution for juvenile coho captured in 2016.**



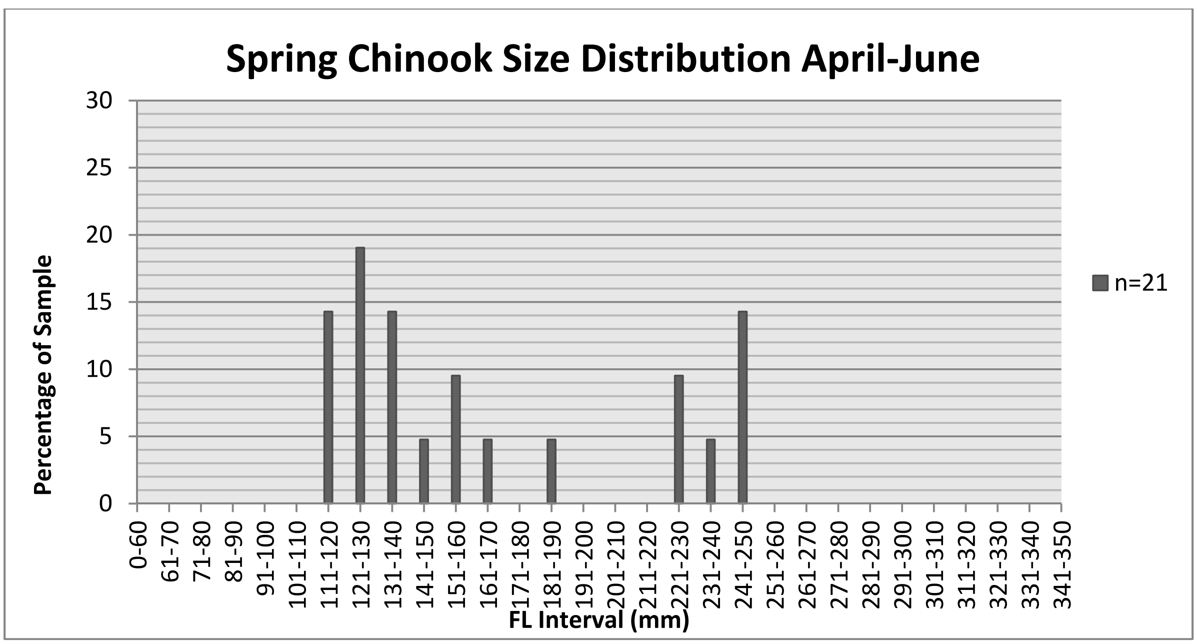
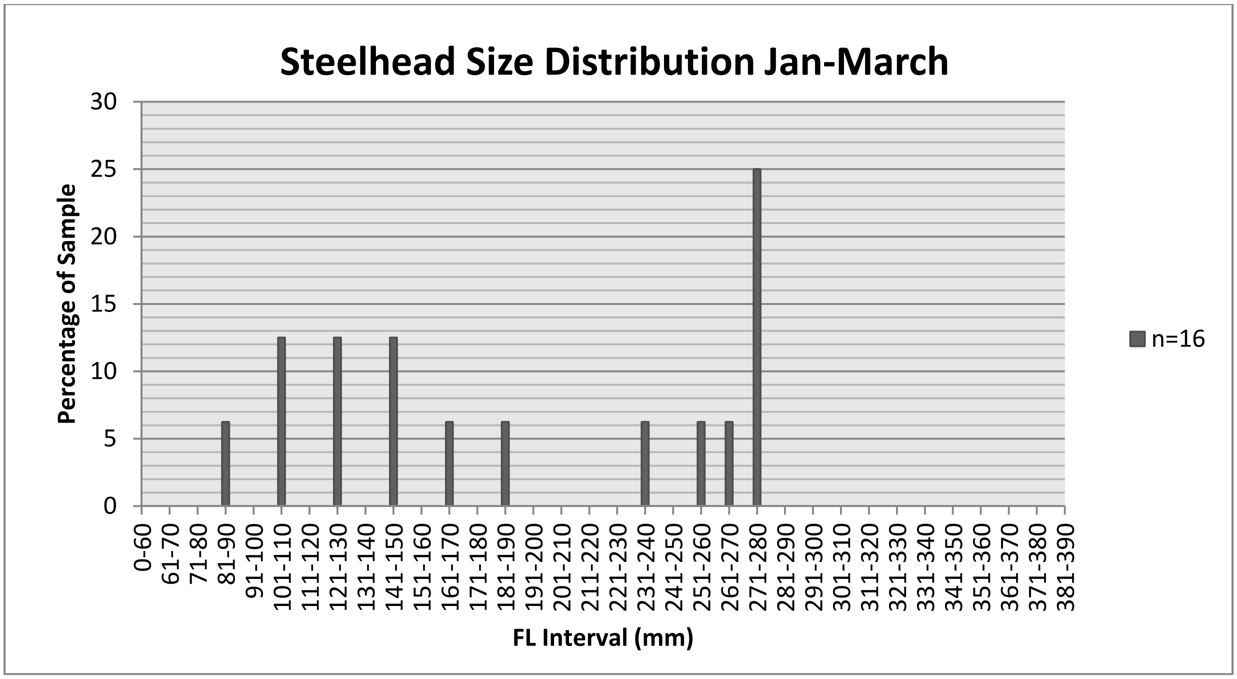




**Figure 3.3-12: Size distribution for juvenile spring Chinook captured in 2016.**



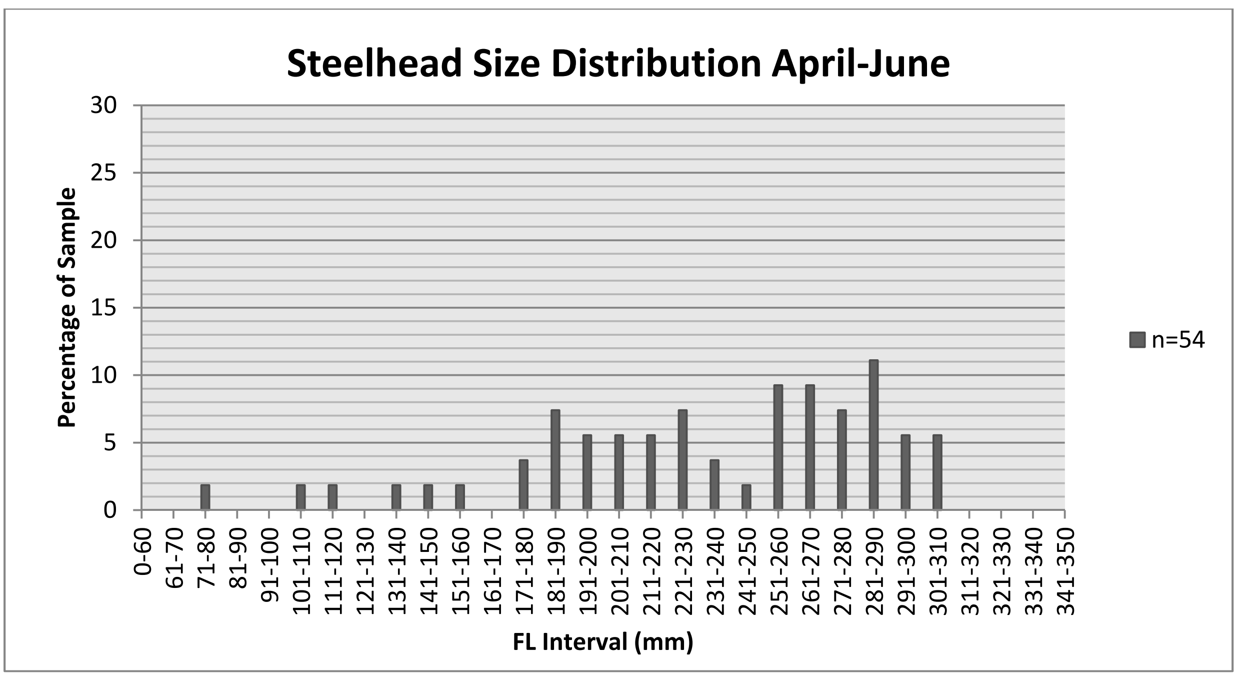




**Figure 3.3-13: Size distribution for juvenile steelhead captured in 2016.**

## 3.4 FSC Collection Efficiency

### 3.4.1 Overview

The use of biotelemetry to measure collection efficiency ($P_{CE}$) of juvenile salmonids at the FSC was further evaluated in spring 2016. This evaluation was in accordance with Section 9.2.1(c) of the Settlement Agreement and based on findings and recommendations from the 2013 pilot study (Courter et al. 2013), 2014 evaluation (Stroud et al. 2014), and 2015 evaluation (Reynolds et.al 2015). Objective 2 of the M&E Plan defines $P_{CE}$ as the percentage of juvenile salmonids emigrating from Swift Reservoir that is available for collection and that is actually collected. A juvenile that is available for collection is one that is detected within the zone of influence (ZOI); the area roughly 150 feet in radius immediately outside the NTS that is influenced by flow entering the FSC. A performance standard of 95 percent or greater for out-migrating smolts[4] was agreed upon for $P_{CE}$.

In 2016, acoustic telemetry was used rather than radio telemetry – similar to 2015. The primary goals of the 2016 Swift Reservoir out-migration study were twofold: 1) determine collection efficiency for juvenile coho, spring Chinook, and steelhead smolts at the FSC; and 2) evaluate how out-migrating smolts interact with the newly installed FSC guide net that was hypothesized to bolster orientation of smolts toward the FSC and thus increase collection efficiency. In addition to these core goals, the 2016 evaluation also explored factors hypothesized to underlie collection efficiency at the Swift Reservoir FSC through logistic regression and visual analysis.

### 3.4.2. Results/Discussion

A detailed report describing the methods and results of the 2016 effort can be found in Appendix B. A brief summary of this report is provided below.

In total, 205 smolts were dual tagged with an acoustic transmitter and PIT tag and then released at the head of Swift Reservoir. Six (6) of these 205 tagged fish displayed detection records that suggest they were preyed upon near the FSC, consequently 199 tagged smolts were used in the analysis Of these fish, 116 were detected near the entrance of the FSC at the ZOI and 34 were successfully collected for an overall collection efficiency of 29.3% (34 of 116; Table 3.4.1).

Fish movements throughout the study area illustrated the tendency of fish to move widely along the front of the FSC, but not to enter the ZOI or the FSC itself. No clear travel path emerges for moving through the forebay toward the FSC. The most heavily used pathway that leads to smolts entering the NTS originated from the northwestern side of the guide net. Notably strong paths did not connect directly from the guide to the NTS, which would be expected if the guide net had helped orient smolts toward the FSC. Instead, tracking data indicate that fish may be sounding under the net, as indicated by subsequent detections from the southern side of the guide net to the northern side of the guide net or vice versa.

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[4]$P_{CE}$ is only calculated for spring Chinook, coho, and steelhead out-migrating smolts. Cutthroat smolts may be included in future studies if it is determined that anadromous life histories exist.

In 2016 80% of collected smolts had been collected before the 7DADA reached 15°C and 99% of all passed before 7DADA exceeded 16°C

While preliminary results of the evaluation indicated that collection efficency nearly doubled from pre-guide net conditions (~30% in 2016 compared to ~15% in 2015), the performance standard was still not being met. Similar to the 2015 evaluation, the results of the 2016 evaluation found that that the majority of the tagged fish did successfully transition through the reservoir and eventually entered the forebay. However, many tagged fish did not transition into the ZOI; but rather milled about the guide-net. Many fish were also found to make successful transitions under the net. Fish species, release day, and reservoir residency time were also found to be significant variables for predicting successful passage.

**Table 3.4.1 Summary of passage metrics for tagged fish released at the head of Swift Reservior by species.**

| Metric | Coho Salmon | Spring Chinook | Steelhead | Total |
|---|---|---|---|---|
| Total tagged (n) | 156 | 3 | 40 | 199 |
| Detected in the Forebay | 140 | 1 | 28 | 169 |
| $P_{RES}$ | 89.7% | 33.3% | 70.0% | 84.9% |
| Detected at ZOI | 98 | 1 | 17 | 116 |
| $P_{ZOI}$ | 62.8% | 33.3% | 42.5% | 58% |
| Captured at FSC | 30 | 0 | 4 | 34 |
| Collection Efficacy ($P_{CE}$) | 30.6% | 0.0% | 23.5% | 29.3% |

## 3.5 Swift FSC Injury and Survival

### 3.5.1 Overview

Injury and survival of captured juvenile salmonids, cutthroat, bull trout, and steelhead kelts were monitored daily on the FSC during 2016 in accordance with Objectives 4 and 5 of the M&E Plan and Section 9.2.1(d) of the Settlement Agreement.

As outlined in the M&E Plan, smolt injury and survival was evaluated based on fish collected in the subsample tanks. The methods outlined in the M&E Plan assume that rates of fish injury and mortality found in subsampled fish would be representative of the general population. PacifiCorp is required to achieve 99.5% survival and less than (or equal) to 2.0% injury (Table 3.5-1).

Each day the FSC was operational, biologists anesthetized juvenile out-migrants collected in the subsample tanks, enumerated fish by species, and inspected them for injury or mortality. Classifications for injury types were grouped into three categories: 1) recordable injuries or injuries caused by collection practices that may substantially decrease the chance of surviving; 2) non-recordable injuries or injuries caused by collection purposes that likely will not decrease the chance of survival; and 3) non-trap related injuries or injuries from natural occurrences prior to fish entering the FSC (Table 3.5-2).

**Table 3.5-1 Specified injury and survival standards.**

| Species and Life Stage | Recordable Injury Rate | Survival Rate |
|---|---|---|
| Chinook, Coho, Steelhead, Cutthroat Smolts | 2.0% | 99.5% |
| Chinook, Coho, Steelhead, Cutthroat Fry | 2.0% | 98.0% |
| Bull Trout | 2.0% | 99.5% |

**Table 3.5-2 Categories used for documenting visible injury at the FSC.**

| Recordable Injury | | Non-Recordable Injury |
|---|---|---|
| Hemorrhaging | Open Wound (No Fungus) | Open Wound (Fungus) |
| Gill Damage | Bruising > 0.5 cm diameter | Bruising $\leq$ 0.5 cm diameter |
| Loss Of Equilibrium | Descaling > 20% | Descaling < or = 20% |

Any mortality observed in the subsample tank was also recorded. Mortality was classified into two categories: 1) trap related mortality; or 2) non-trap related mortality. Biologists utilized various signifiers to determine whether or not mortality was caused by collection practices. Signifiers included presence of fungus, gill coloration, inspection for cause of death (i.e., descaling, brain trauma, predation, hook & line injury), and *rigor mortis*.

As specified in the current M&E Plan, injury and survival rates were calculated daily and are shown in Equation 3.5-1 and Equation 3.5-2, respectively.

$$\boldsymbol{R_{Inj} = \frac{SS_{Inj}}{SS_{Total}}} \qquad \textbf{Equation 3.5-1}$$

Where:

$R_{Inj}$ = Observed daily injury rate per species;
$SS_{inj}$ = Number of injured fish per species in subsample, mortalities are not included;
$SS_{Total}$ = Total number of fish per species in subsample, mortalities are not included.

$$\boldsymbol{CS = \frac{M_{SS}}{SS_{Total}}} \qquad \textbf{Equation 3.5-2}$$

Where:

$CS$ = Observed collection survival rate per species;
$M_{SS}$ = Number of mortalities of a particular species and age class in the subsample;
$SS_{Total}$ = Total Number of fish of a particular species and age class in the subsample.

## 3.5.2 Results/Discussion

*INJURY RATE*

Combined annual injury rates for each target species ranged from 0 to 1.1 percent (Table 3.5-3). Juvenile Chinook (parr and smolt) had the highest overall injury rate (1.1%), followed by juvenile coho (0.3%), steelhead (0.1%) and cutthroat (0.01%). Descaling accounted for the greatest proportion of the injuries observed (greater than 80%) in all species, followed by eye hemorrhaging (8.1%) and bruising (5.4%) (Figure 3.5-2). No injuries were observed among coho fry (n=856), cutthroat fry (n=32), steelhead fry (n=32), or Chinook fry (n=5). Similarly, injuries were not observed on any of the adult steelhead or bull trout collected.

Overall, annual injury rates for all juvenile salmonid species (smolt and parr) and adult fish met the required performance standard maximum of 2.0%. Only juvenile Chinook were found to have an injury rate greater than 0.4%. However, these fish were almost exclusively comprised of fish from the acclimation program and were susceptible to descaling due to the prevalence of Bacterial Kidney Disease (BKD).

PacifiCorp will continue to address the causes of injury in the future. Debris loading on the fry and smolt separator bars continues to be the major source for fish injury. As a temporary solution to this problem, PacifiCorp staffed the FSC around the clock to clear debris from the separator bars during peak migration periods. PacifiCorp may install a debris conveyor on the NTS in the future to minimize the amount of debris that makes it into the FSC.

**Table 3.5-3 Annual injury rates for target species collected at the FSC are shown with the associated 95% confidence interval. [a] Mortalities with injuries are not assigned as injured fish; they are assigned to mortality totals. [b] The number sampled for injury rate calculations does not include mortalities**

| Species | No. Injured[a] | No. Sampled[b] | Injury Rate (%) |
|---|---|---|---|
| Coho (Fry) | 0 | 836 | 0.0 |
| Chinook (Fry) | 0 | 5 | 0.0 |
| Steelhead (Fry) | 0 | 32 | 0.0 |
| Cutthroat (Fry) | 0 | 32 | 0.0 |
| **Combined (Fry)** | **0** | **884** | **0.0** |
| | | | |
| Coho (Parr & Smolt) | 196 | 28,971 | 0.68 ± 0.09 |
| Chinook (Parr & Smolt) | 40 | 3,520 | 1.14 ± 0.35 |
| Steelhead (Parr & Smolt) | 3 | 714 | 0.42 ± 0.47 |
| Cutthroat (Parr & Smolt) | 1 | 532 | 0.19 ± 0.37 |
| **Combined (Parr & Smolt)** | **240** | **33,737** | **0.71 ± 0.09** |
| | | | |
| Steelhead Adults | 0 | 36 | 0.0 |
| Steelhead Kelts | 0 | 66 | 0.0 |
| Bull Trout | 0 | 40 | 0.0 |

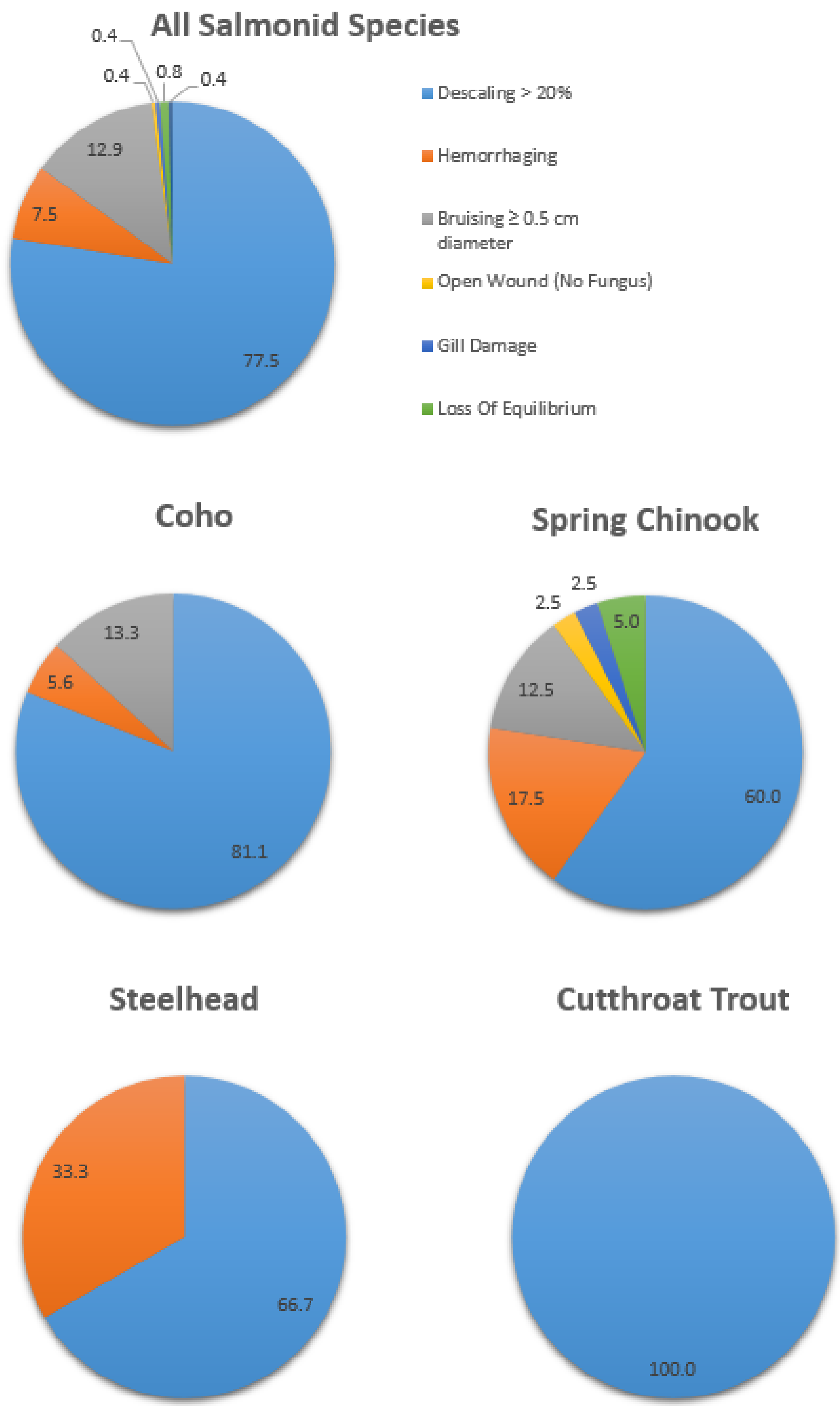


**Figure 3.5-2: Composition of injury type occurrences by species. Percentages reflect parr and smolts numbers collected that are referenced in Table 3.5-3.**

*SURVIVAL RATE*

In the absence of juvenile Release Ponds, annual survival rates were based solely on collection survival ($S_{COL}$) because the Release Ponds were not yet constructed in 2016. Transported fish were directly released into the Lewis River below Merwin Dam (Pekins Ferry Boat Launch at near rivermile three) and consequently, a true estimate of transport survival ($S_{TRAN}$) was not possible.

Annual survival rates among all target species and life-stages passing through the FSC ranged from 85.4 to 100 percent (Table 3.5-4). Cutthroat Trout had the highest survival rate (99.2%) for parr and smolt life-stages combined, followed by coho (97.6%), steelhead (98.5%), spring Chinook (96.5%), bull trout (90.0%), and adult steelhead (85.7). No mortalities were observed among any species of salmonid fry (n=925).

Nearly all mortality observed was associated with high debris loading and accumulation on the fish sorting bars and in the holding tanks. This is a particular problem during high run-off periods in the winter and early-spring when sub-yearling out-migrants (parr) are prevalent. Modifications to the sorting areas and tanks are being considered by PacifiCorp to help manage debris accumulation and further reduce mortality.

**Table 3.5-4 Annual survival rates for juvenile salmonids (parr and smolt), cutthroat, bull trout, and adult steelhead.**

| Species | No. of Mortalities | No. Sampled | Survival% (CS) | Combined Survival% (CS) with 95%CI |
|---|---|---|---|---|
| *Coho Parr* | 378 | 10,431 | 96.4 | 97.6 ± 0.20 |
| *Coho Smolts* | 309 | 18,540 | 98.3 | |
| *Chinook Parr* | 26 | 673 | 96.1 | 96.5 ± 0.61 |
| *Chinook Smolts* | 98 | 2,847 | 96.6 | |
| *Steelhead Parr* | 0 | 45 | 100 | 98.5 ± 0.90 |
| *Steelhead Smolts* | 11 | 669 | 98.4 | |
| *Cutthroat(> 13 inches)* | 0 | 32 | 100 | 99.2 ± 0.73 |
| *Cutthroat (< 13 inches)* | 4 | 500 | 99.2 | |
| | | | **Overall:** | 97.6 ± 0.16 |
| | | | | |
| *Steelhead Adults* | 5 | 36 | 86.1 | 85.7 |
| *Steelhead Kelts* | 7 | 48 | 85.4 | |
| *Bull Trout* | 4 | 40 | 90.0 | 90.0 ± 9.30 |

**Table 3.5-5 Annual survival rates for salmonid fry.**

| Species | No. of Mortalities | No. Sampled | Survival% (CS) |
|---|---|---|---|
| *Coho Fry* | 0 | 856 | 100 |
| *Chinook Fry* | 0 | 5 | 100 |
| *Steelhead Fry* | 0 | 32 | 100 |
| *Cutthroat Fry* | 0 | 32 | 100 |
| | | **Overall:** | **100** |

## 3.6 Swift Powerhouse Entrainment Evaluation

Assessing the proportion of fish entering the intake of the Swift No.1 Powerhouse is required under section 9.2.1(f) of the Settlement Agreement and identified as Objective 3 of the M&E Plan. However, this M&E Objective will not be quantified until downstream passage facilities are installed at Yale and Merwin Dams.

## 3.7 Overall Downstream Survival (ODS)

### 3.7.1 Overview

The Settlement Agreement requires that the Utilities achieve an overall downstream survival (ODS) rate of greater than or equal to 80%[5]. ODS is defined in Section 4.1.4 of the Settlement Agreement as:

> *The percentage of juvenile anadromous fish of each of the species designated in Section 4.1.7 that enter the reservoirs from natal streams and survive to enter the Lewis River below Merwin Dam by collection, transport and release via the juvenile fish passage system, passage via turbines, or some combination thereof, calculated as provided in Schedule 4.1.4.*

In other words, ODS is the percentage of the fish entering the Lewis River hydroelectric project reservoirs (the Project) that and are successfully captured and released alive below the Project (e.g. Merwin Dam).. It should be noted that Schedule 4.1.4 of the Settlement Agreement contains a caveat that the methodology described in the Schedule needs to be ground-truthed and may not be the best method to use.

Initially, ODS will be measured from the head of Swift Reservoir to the exit of the Release Ponds located downstream of Merwin Dam (Figure 2.1-1). Estimates of ODS will be developed for coho, spring Chinook, steelhead and sea-run cutthroat trout. ODS estimates for sea-run cutthroat trout will be delayed until data indicate that this cutthroat life history is present in the upper Lewis River basin and that the number of juveniles produced is sufficient, as determined by the USFWS, for experimental purposes.

Passive Integrated Transponder (PIT) tags, compatible with those used throughout the Columbia Basin for salmonid evaluations, and direct enumeration of fish collected and transported from the Swift Floating Surface Collector (FSC) will be used to develop estimates of ODS. All PIT tags used will be entered into the Pacific Northwest Region PIT tag database (PTAGIS).

[5] An ODS of greater than or equal to 80% is required until such time as the Yale Downstream Facility is built or the Yale in Lieu Fund becomes available to the Services, after which ODS shall be greater than or equal to 75%. The parties to the Settlement Agreement acknowledge that ODS rates of 80% or 75% are aggressive standards and will take some time to achieve.

Consistent with the Settlement Agreement, juveniles passing Swift Dam either through the turbines or spill will not be counted toward meeting the ODS standard because they are unlikely to survive passage through multiple dams and reservoirs not equipped with passage facilities.

### 3.7.1 METHODS

The methods proposed for developing estimates of ODS are as follows:

- Test fish will be obtained from a screw trap operated at the head of Swift Reservoir or at the FSC. Fish collected at the FSC will only be used if enough fish cannot be collected at the screw trap. Preference will be to use fish collected at the screw trap as these fish would have not been exposed to the reservoir environment; an exposure that may alter fish behavior, and thus interpretation of study results.

- Fish captured at the traps will be identified to species, measured for length and a subsample tagged with PIT-tags. Only fish greater than, or equal to, 60mm in length will be tagged. On an annual basis, the ACC will evaluate the appropriate size limits for tagging.

- Fish will be released at the head of Swift Reservoir weekly throughout the major part of the migration season (April-June). A total of 996 fish of each species will be released weekly in the spring in proportion to the run-timing of each species. PIT tag releases will continue into summer or fall as long as a persistent juvenile migration exists

- Sample size for the release was based on a reservoir survival rate of 80%, tag detection probability of 95% and a precision of 0.025. The test fish will be held for 24 hours prior to release to quantify handling mortality.

- PIT-tag detectors will be located on the FSC and at the exit of the release ponds and will generate the tag detection histories necessary to estimate ODS.

- The FSC, transport trucks and release ponds (when completed) will be examined daily by biologists to determine the number of fish killed during the handling and transport processes. All dead fish will be examined for the presence of a PIT tag. Dead tagged fish found in the FSC and release ponds would be assigned to collection loss ($S_{COL}$) and transport loss ($S_{TRAN}$), respectively.

- Once CE exceeds 60 percent, 50 dead PIT-tagged fish will be released into the FSC over the course of the season as a check on the ability of the biologists to detect and recover dead fish. If tag recoveries are less than 100%, estimates of ODS will be adjusted based on the calculated error rate.

The seasonal ODS estimate will be based on pooling release–recapture data over the season. Because some proportion of tagged fish are likely to overwinter in the reservoir, any fish captured in subsequent years will be retrospectively added to the ODS estimate for their release year. The ODS calculation under the intended operations (i.e., after completion of the Release

Ponds) is shown in Equation 3.7-1. The ODS calculation used in the 2016 study (absent of $S_{TRAN}$) is shown in Equation 3.7-2.

$$ODS = S_{RES} * S_{COL} * S_{TRAN}$$ **Equation 3.7-1 (with release ponds)**

Where:

$S_{RES}$ = Survival probability through reservoir;
$S_{COL}$ = Survival probability through the collector;
$S_{TRAN}$ = Survival probability through the smolt transport system

$$ODS = S_{RES} * S_{COL}$$ **Equation 3.7-2 (without release ponds - 2016)**

Where:

$S_{RES}$ = Survival probability through reservoir
$S_{COL}$ = Survival probability through the collector
$S_{TRAN}$ = Survival probability through the smolt transport system.

### 3.7.2 RESULTS/DISCUSSION

Only PIT tag interrogations at the FSC recorded on or before December 31st, 2016 were included in the ODS calculations (Table 3.7-1). No dead PIT tagged fish used in the ODS study were found in the FSC. Hence, $S_{COL}$ was considered 100 percent for each species during 2016. Since $S_{TRAN}$ was not calculated and assumed to be 100 percent in 2016, ODS estimates during the 2016 study were equal to $S_{RES}$.

The M&E Plan calls for 996 tagged fish per species to be released over a six week period during the particular species respective run-timing in order to achieve the desired statistical power. To capture fish for tagging a single 8 feet diameter screw trap was operated in the upper Lewis River near Eagle Cliff from March 24 to June 30, 2016. Low numbers of fish were captured by the screw trap overall in 2016. Because of the lack of adequate numbers of fish to tag, no species received the required 996 tags; during the study period, only 686 coho, 2 Chinook, 22 cutthroat, and 79 steelhead were PIT tagged and released. Of the 686 PIT tagged coho, 594 were non-naïve fish that were captured and tagged at the FSC then transported and released back at the head of the reservoir. The resulting annual ODS estimates are 33% (± 3.5%) for coho, 0% for spring Chinook, 4.5% (± 3.5%) for cutthroat and 15% (± 8.6) for steelhead (Table 3.7-1). The ODS estimate for cutthroat should be interpreted with the understanding that little is yet known about the life history patterns of cutthroat in the Upper Lewis River watershed.

**Table 3.7-1: Annual ODS estimate for each species (functionally $S_{RES}$). ODS performance standard for all species is ≥ 80 percent. [1] Lower bound of cutthroat ODS 95% CI should be interpreted as zero (0) percent.**

| Species | Tagged and Released in 2016 | FSC Recaptured in 2016 | 2016 ODS (%) with ±95% CI |
|---|---|---|---|
| Coho | 686 | 227 | 33 ± 3.5 |
| Steelhead | 79 | 12 | 15 ± 7.8 |
| Cutthroat | 22 | 1 | 4.5 ± 8.6 [1] |
| Spring Chinook | 2 | 0 | 0 |

The M&E Plan addresses the fact that a portion of tagged fish are likely to overwinter in the reservoir and that any fish captured in subsequent years will be retrospectively added to the ODS estimate for their release year. The adjusted 2015 ODS estimate are summarized below in Table 3.7-2. An additional 78 tagged coho from the 2015 ODS study were captured by the FSC during 2016, this was triple the amount that were captured during 2015; raising the 2015 ODS estimate from 6.5 to 27 percent. An additional 6 steelhead and 1 Chinook that were tagged in the 2015 ODS study were captured by the FSC in 2016. Cutthroat were not included in the 2015 ODS evaluation.

**Table 3.7-2: 2015 adjusted annual ODS estimate for each species (functionally $S_{RES}$) is shown. ODS performance standard for all species is ≥ 80 percent.**

| Species | Tagged and Released in 2015 | FSC Recaptured 2015 | 2015 ODS (%) with ±95%CI | FSC Recaptured 2016 | Total Recaptured (Combined Years) | 2015 Combined ODS (%) with ±95%CI |
|---|---|---|---|---|---|---|
| Coho | 382 | 25 | 6.5 ± 2.5 | 78 | 103 | 27 ± 4.5 |
| Steelhead | 117 | 15 | 12.8 ± 6.1 | 6 | 21 | 18 ± 7.0 |
| Cutthroat | 0 | 0 | NA | 0 | 0 | NA |
| Spring Chinook | 37 | 0 | 0 | 1 | 1 | 2.7 ± 5.2 |

# 4.0 UPSTREAM COLLECTION AND PASSAGE METRICS

## 4.1 Summary

The historic adult fish trap at Merwin Dam was operated by PacifiCorp staff until June 28th, 2013, when it was decommissioned for construction activities associated with the new passage facility. The new upstream sorting facility at Merwin Dam was considered substationally completed in April 2014, and has actively operated since.

All adult salmonids collected were identified to species and sorted by origin (i.e., hatchery or wild), broodstock (i.e., hatchery or supplementation), or as upstream target species.

A total 23,570 fish were captured (recaptured fish counts include 3,845 hatchery summer steelhead, 97 blank wire tag winter steelhead, and 14 wild sockeye) at the Merwin Trap in 2016 (Table 4.1-1). Among the species collected, summer steelhead accounted for the majority of fish captured (n=10,110) followed by late run coho (n=5,285), early run coho (n=4,366), winter steelhead (n=2,980), spring Chinook (n=399), fall Chinook (n=284), cutthroat (n=75), sockeye (n=46), various resident fishes (n=24), and chum salmon (n=1).

A total of 6,265 hatchery summer steelhead were captured at Merwin Trap and marked with a caudal clip. These fish were transported and released back into the lower Lewis River as part of the Washington Department of Fish and Wildlife Fish Recycle Program. A total 3,845 summer steelhead were then recaptured at Merwin Trap. Once recapture, fish were then surplused.

There was a notable increase in the proportion of wild early run coho that returned to MFCF in 2016, when compared to previous years. Approximately 34.5% of all early run coho that returned in 2016 were of wild origin, compared to 11.2% and 6.5% in 2014 and 2015, respectively. Also of note was the return of the first PIT tagged adult coho that had been tagged at the FSC as a smolt.

A total of 4,111 early coho , 3,235 late coho , 772 blank wire tag winter steelhead, and 73 cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program in 2016 (Table 4.1-2). Of the 4,111 early coho that were transported upstream, 3,049 were collected at Merwin Trap, and 1,062 were collected at Lewis River Hatchery. All wild early coho collected at either location were transport upstream. All late coho transported upstream were collected at Merwin Trap (n=3,235). Only hatchery origin late-coho were transported upstream. Of the 772 winter steelhead transported upstream, 769 were captured at Merwin Trap, and 3 winter steelhead were captured at Lewis River Hatchery. All transported winter steelhead were blank wire tag fish; no true wild winter steelhead were transported. All 73 adult costal cutthroat collected at Merwin Trap were transported upstream..

**Table 4.1-1: Total fish collected at Merwin Trap during 2016. Resident rainbow trout and cutthroat were not gender-typed. [a] Counts of male and female spring Chinook may vary slightly from those reported by WDFW broodstock counts.**

| **Characteristic** | *AD Clip* | | | *CWT* | | | *Wild* | | | *Wild Recap* | | | *Wild-BWT* | | *Recap* | | *Misc* | **Total** | **%** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | M | F | J | M | F | J | M | F | J | M | F | J | M | F | M | F | Not sexed | | |
| *Spring Chinook [a]* | 161 | 169 | 53 | | | | 7 | 8 | 1 | | | | | | | | | **399** | 1.7 |
| *Fall Chinook* | 72 | 96 | 16 | | | | 44 | 48 | 8 | | | | | | | | | **284** | 1.2 |
| *Early Coho* | 1002 | 1118 | 321 | 188 | 166 | 64 | 510 | 596 | 401 | | | | | | | | | **4366** | 18.5 |
| *Late Coho* | 2289 | 2082 | 85 | 353 | 315 | 18 | 69 | 63 | 11 | | | | | | | | | **5285** | 22.4 |
| *Summer Steelhead* | 2533 | 3732 | | | | | | | | | | | | | 1578 | 2267 | | **10110** | 42.9 |
| *Winter Steelhead* | 893 | 1089 | | | | | 27 | 23 | | | | | 411 | 440 | 52 | 45 | | **2980** | 12.6 |
| *Sockeye Salmon* | | | | | | | 15 | 17 | | 3 | 11 | | | | | | | **46** | 0.2 |
| *Chum Salmon* | | | | | | | | 1 | | | | | | | | | | **1** | 0.004 |
| *Pink Salmon* | | | | | | | | | | | | | | | | | | **0** | 0 |
| *Cutthroat (>13 inches)* | | | | | | | | | | | | | | | | | 73 | **73** | 0.3 |
| *Cutthroat (< 13 inches)* | | | | | | | | | | | | | | | | | 2 | **2** | 0.01 |
| *Rainbow (< 20 inches)* | | | | | | | | | | | | | | | | | 24 | **24** | 0.1 |
| *Bull Trout (> 13 inches)* | | | | | | | | | | | | | | | | | | **0** | 0 |
| *Bull Trout (< 13 inches)* | | | | | | | | | | | | | | | | | | **0** | 0 |
| | | | | | | | | | | | | | | | **Total** | | | **23,570** | 100 |

**Table 4.1-2: Total fish transported above Swift Dam in 2016**

| Species | Male | Female | Jack | Not sexed | Female:Male Ratio | Jack:Adult Ratio | Total |
|---|---|---|---|---|---|---|---|
| *Spring Chinook* | - | - | - | - | - | - | *0* |
| *Early Coho* | 1786 | 1789 | 536 | - | 0.77 | 0.15 | *4111* |
| *Late Coho* | 1,644 | 1,588 | 3 | - | 0.96 | 0.0009 | *3,235* |
| *Winter Steelhead* | 382 | 390 | - | - | 1.02 | - | *772* |
| *Cutthroat >13"* | - | - | - | 73 | - | - | *73* |
| *Bull Trout >13"* | - | - | - | - | - | - | *0* |
| | | | | | | **Total** | *8,191* |

## 4.2 Adult Passage Survival

### 4.2.1 Overview

Section 9.2.1(h) of the Settlement Agreement require that upstream passage survival (UPS) of adult salmonids and bull trout to be equal to or greater than 99.5%. The methods to calculate adult passage survival are outlined in Objective 9 of the M&E Plan. Adult bull trout and cutthroat trout are defined as fish with fork length greater than 13 inches (330 mm). UPS is defined as the survival from the time adult target species enter the adult upstream facility to their release above Swift Dam. UPS is calculated based on Equation 4.2-1:

$$UPS = 1 - \frac{AD_{TRAP} + AD_{REL}}{N} \qquad \textbf{Equation 4.2-1}$$

Where:

$N$ = Number of total adults collected

$AD_{TRAP}$ = Number of dead adults in trap

$AD_{REL}$ = Number of dead adults at release site

### 4.2.2 Results/Discussion

A total 8,191 adult salmonids (4,111 early coho, 3,235 late coho, 772 winter steelhead, and 73 cutthroat) were transported upstream throughout the migration period in 2016. All cutthroat trout survived the trapping and transport processes resulting in a UPS of 100 percent. One blank wire tag winter steelhead mortality was observed at the Merwin fish sorting facility, resulting in a 99.97 percent UPS. A total of 20 coho mortalities were observed during transport in 2016, of which 15 were in a single event. A total of 21 mortalities were observed across all species, resulting in a UPS of 99.74 percent (Table 4.2-1) . No spring Chinook were transported upstream in 2016.

**Table 4.2-1: Overall upstream passage survival for Merwin Fish Collection Facility in 2016.**

| Species | Number Transported | Trap Mortalities | Transport Mortalities | Upstream Passage Survival (%) |
|---|---|---|---|---|
| Early Coho | 4,111 | 13 | 5 | 99.56 |
| Late Coho | 3235 | 2 | 0 | 99.94 |
| Winter Steelhead | 772 | 1 | 0 | 99.97 |
| Coastal Cutthroat | 73 | 0 | 0 | 100 |
| Total | 8,191 | 15 | 5 | 99.74 |

## 4.3 Adult Trap Efficiency

### 4.3.1 Overview

Adult trap efficiency (ATE) is defined in Section 4.1.4 of the Settlement Agreement as:

> *The percentage of adult Chinook, coho, steelhead, bull trout, and sea-run cutthroat that are actively migrating to a location above the trap and that are collected by the adult trap at Merwin Dam.*

Based on the methods outlined in Objective 10 of the M&E Plan, the first year of study began in spring 2015. During that initial year, all three study species were evaluated including: winter steelhead, spring Chinook salmon, and coho salmon. However, due to low return rates of spring Chinook and coho salmon, samples sizes of these two species were well below the target of approximately 150 fish. Results of the 2015 evaluation indicated a relatively high success rate for tagged fish locating the trap entrance, but lower rates of fish being successfully captured by the fish crowder and lift assembly.

In 2016, In 2016, PacifiCorp implemented a second year of study. In addition to generating core passage metrics, the 2016 study focused efforts on resolving fish behaviors in and around the fish crowder and lift assembly using an ARIS sonar camera. Low return numbers of both spring Chinook and coho salmon in 2016 prevented inclusion of these species in the study; consequently, the 2016 ATE study focused exclusively on winter steelhead.

### 4.3.1 Results/Discussion

A detailed report of the first year of data collection (2016) is provided in Appendix C.

Similar to the observations made in 2015, results of the 2016 evaluation also indicated a relatively high success rate for tagged fish locating the trap entrance ($P_{EE}$), but lower rates of fish being successfully captured ($ATE_{test}$) (Table 4.3.1). This discrepancy was discerned from the trap inefficiency ($T_i$) metric, which reflects the proportion of fish that located the trap but were not captured. Moreover, based on both (1) initial ARIS camera data and (2) operational scenario modeling of network analysis output, it appears that (A) fish passage is constrained at the hopper and that (B) the frequency of fish crowder operation strongly affects rate of successful passage. In general, fish were found to move in and out of the trap entrance and fish crowder at will; in some instances making over 100 trips between the tailrace and the trap without being captured by the fish crowder and lift assembly. To prevent fish from returning to the tailrace once they have entered the trap, a fyke was installed on the upstream side of the Pool 1-2 ladder weir in November 2016. This modification to the existing trap will be evalauated in 2017

**Table 4.3.1 Summary of passage metrics for tagged fish released into the tailrace of Merwin Dam in 2016.**

| Metric | Coho Salmon | Spring Chinook | Steelhead |
|---|---|---|---|
| Total tagged (n) | *NA* | *NA* | 148 |
| Entered the Tailrace | *NA* | *NA* | 128 |
| Entered the Trap | *NA* | *NA* | 119 |
| Trap Entrance Efficiency ($P_{EE}$) | *NA* | *NA* | 93%<br>(87% – 96%) |
| Captured | *NA* | *NA* | 94 |
| Collection Efficacy ($P_{CE}$) | *NA* | *NA* | 73%<br>(65% - 80%) |

# 4.4 Spawn Timing, Distribution, and Abundance of Transported Fishes

## 4.4.1 Overview

Section 9.2.2 of the Settlement Agreement identified the need to determine the spawn timing, distribution, and abundance for transported anadromous species that are passed upstream of Merwin Dam. The primary objective of this task is to identify preferred spawning areas in order to: 1) inform revisions to the Hatchery and Supplementation Plan (H&S Plan; PacifiCorp and Cowlitz PUD 2009) and the Upstream Transport Plan (PacifiCorp 2009); and 2) guide the ACC in determining how to direct restoration efforts with the Aquatics Fund.

Two methodologies for determining spawn timing, distribution, and abundance of transported fishes were developed. For adult coho salmon, comprehensive spawning ground surveys were conducted in the potentially accessible river and stream reaches upstream of Swift Dam in 2016. No adult spring Chinook were transported upstream in 2016. Due to limited access and anticipated heavy snow accumulations during the spawning season for winter steelhead, a combination of aerial radio telemetry surveys, fixed-station radio antennas, aerial red counts, and single pass electrofishing surveys for young-of-the-year steelhead (during the following summer) were conducted. A detailed description of each method is outlined in Objective 15 of the M&E Plan.

In addition to evaluating spawn timing, distribution, and abundance of transported species, PacifiCorp also continued to implement a seed plant program in 2016. This program was developed based on results of earlier observations which indicated that by distributing a proportion of the adults further upstream did appear to improve fish distribution (summarized in detail in Appendix F in the 2015 Annual Fish Passage Program Report). Three additional releases sites were established in the upper watershed of Swift Reservoir in 2016. These released sites included the Muddy River Bridge, the Clear Creek Bridge, and the upper Lewis River Bridge near Crab Creek. In an effort to promote a wider distribution and habitat utilization by transported fish, a proportion of fish transported upstream were released at these remote locations (Table 4.4.1.). Radio telemetry combined with a number of aerial surveys were used to evaluate winter steelhead behavior and movement. Spawninig surveys were used to determine distibutiuon of coho salmon.

**Table 4.4.1 Summary of fish releases upstream of Swift Reservior as part of the 2015 seed plant evaluation.**

| | Eagle Cliff | Upper Watershed | | | | Combined Total |
|---|---|---|---|---|---|---|
| **Winter Steelhead** | | Muddy River Bridge | Clear Creek Bridge | Upper Lewis (Crab Creek) | Total | |
| Untagged | 353 | 111 | 113 | 102 | 360 | 679 |
| Radio Tagged | 59 | 16 | 14 | 4 | 34 | 93 |
| Total | 412 | 127 | 127 | 106 | 456 | 772 |
| **Coho Salmon** | | | | | | |
| Coho Type-S | 4,028 | 45 | 38 | 0 | 83 | 2% |
| Coho Type-N | 2,789 | 170 | 276 | 0 | 446 | 14% |
| Total | *6,817* | *215* | *314* | *0* | *529* | *7%* |

### 4.4.2 Results/Discussion

Monitoring of radio tagged winter steelhead transported to upper basin sites and released revealed that fish remained and were assumed to have spawned in these general areas. Distibution of radio tagged steelhead in 2016 was consistent with those detection in 2015, which indicated that seed planting efforts help distribute winter steelhead throughout the upper basin during reintroduction (Appendix D).

Data collection on the spawn timing, distribution, and abundance of transported fishes was completed in mid-November, 2016. At the time of this initial review draft, PacifiCorp has not received the results of this 2016 effort. When complete, the results (for coho salmon) will be attached as Appendix E to this report.

# 5.0 OCEAN RECRUIT ANALYSIS

## 5.1 Overview

An analysis of ocean recruitment is stipulated in the Settlement Agreement to determine when the hatchery and natural adult production targets established for the upstream passage program were met. These targets were defined in Section 8.1 of the Settlement Agreement and described as:

> *"…total escapement (fish that naturally spawned above Merwin Dam and hatchery fish) plus harvest (including ocean, Columbia River, and Lewis River Harvest)."*

For this analysis, the average number of ocean recruits over a five-year period will be evaluated. That is, five consecutive brood years. These data will be evaluated to determine if and when hatchery production levels should be altered. A detailed description of the methodology for this analysis is outlined in Objective 12 of the M&E Plan. The M&E Work Group settled on using three different methods of estimation including: 1)Return-year recruitment estimates; 2) Brood year recruitment estimates; and, 3) Fishery plus escapement. These three approaches will be used to supply information for run-reconstruction estimates of each return year. Steelhead are an exception because of their multi-year life cycle so WDFW recommends using a catch plus escapement approach. Some of this work depends on an accurate creel census program to estimate fishery-related mortalities but a creel program will not be implemented until adequate numbers of spring Chinook return to warrant the effort.

## 5.2 Results/Discussion

Ocean recruit analysis was initiated in fall of 2013 and continued through the rest of the year. Half-way through the process of determining a methodology, investigators realized that the use of coded-wire tags (CWT) and the Regional Mark Information System (RMIS) does not account for CWT detection in fish that still have their adipose fin. The alternative methods for estimating ocean recruits is outlined in the latest version of the M&E Plan which will be completed by the end of February 2017. It will take at least five years of analysis before investigators can confidently report ocean recruit numbers and begin evaluating hatchery goals for the Lewis River.

# 6.0 PREFORMANCE MEASURES FOR INDEX STOCKS

## 6.1 Overview

The H&S Plan (PacifiCorp and Cowlitz PUD 2009) recommends that other Lower Columbia River stocks be used as index groups to determine whether the success or failure of the Lewis River reintroduction program is the result of in-basin or out-of-basin factors. This would be determined by comparing the survival rates of hatchery and natural-origin fish produced in other basins (such as the Cowlitz River) with releases made in the Lewis River.

## 6.2 Results/Discussion

Since adult returns of natural-origin fish from the upper Lewis River have not occurred in numbers large enough for meaningful analysis, this metric will be postponed until larger natural-oginadult returns are realized.

# 7.0 REINTRODUCED AND RESIDENT FISH INTERACTIONS

## 7.1 Overview

As called for in Section 9.7 of the Settlement Agreement, PacifiCorp will monitor the interaction between reintroduced anadromous salmonids and resident fish species. Of specific interest to the Settlement parties was the possible effect resident trout released in Swift Reservoir may have on reintroduced salmonids and the effect of anadromous fish introductions on the kokanee populations in Yale Lake. Additionally, concern was expressed that anadromous fish may impact the health and viability of ESA listed bull trout populations. This task is one of the assignments of the Fish Passage Feasibility Study conducted by the US Geological Survey and University of Washington, Department of Fisheries. The final report was issued in December 2016 (PacifCorp 2016).

## 7.2 Results/Discussion

The USGS/UW group completed their analysis and provided results as follows:

1) Utilized existing data and empirical data to identify the structure of food webs in the three reservoirs;
2) Provided estimates of predation potential and consumption of juvenile salmonids by resident native and non-native species across different seasons;
3) Provided estimates of potential competition among different resident species and anadromous salmonids for resources;
4) Quantified spatial overlap within Pine Creek and habitat use by anadromous smolts and resident fishes; and,
5) Provided estimates of predation and competition among species in Pine Creek using stable isotope methods.

This effort covered a three-year period but the M&E subgroup suggested that this effort be repeated to assess interactions once the reintroduction program is full operational.

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# APPENDIX

## APPENDIX A

## SUMMARY OF 2016 ACCLIMATION FISH RELEASES AND EVALUATION RESULTS

**2016 Spring Chinook Acclimation Planting Schedule and Evaluation Plan**
Prepared by PacifiCorp
August 24, 2016
***Final***

## Background

Section 8.8.1 of the Lewis River Settlement Agreement states:

> "*Beginning upon completion of the Swift Downstream Facility, the Licensees shall place juvenile salmonid acclimation sites in areas reasonably accessible to fish hauling trucks and in practical areas in the upper watershed above Swift No. 1 Dam, as determined by the Licensees in Consultation with the Yakima Nation and the ACC…"*

To meet this requirement, three acclimation sites were constructed in the upper Lewis River basin upstream of Swift Reservoir. Two of these sites (Muddy River and Clear Creek Acclimation Ponds) were designed to take advantage of natural habitat by reconditioning side channels and using flow control structures to manage in-flow from the main river channel and to maintain adequate water elevation in the ponds. Construction of these sites was completed in fall 2013. The third site diverted water from Crab Creek, which served as inflow to a holding tank placed downstream near the confluence of Crab Creek and the Lewis River. The Crab Creek site was completed in fall 2015. The original intent of all three sites was to hold fish in the early spring for up to 6-weeks before allowing for volitional passage into the river. A total of 38,000 spring Chinook were originally to be stocked at Muddy River site, 19,000 at the Clear Creek site, and 15,000 at the Crab Creek site annually.

Due to a number of unforeseen challenges, these sites have not been utilized as intended. A procedural decision made by the Aquatic Coordination Committee (ACC) to begin releasing acclimation fish in the fall as opposed to holding them in the hatchery and releasing them the following spring has also complicated the use of these sites[1]. A brief summary describing each of these challenges is provided below:

- *Muddy River Acclimation Pond* – Following completion of the pond, the Muddy River site experienced too low of dissolved oxygen levels to support juvenile salmonid life (< 4 mg/L) due to high levels of iron-oxidation from iron bacteria. Aeration units were tried, but they did not increase dissolved oxygen to suitable levels. Pending actions to remedy the iron problem, acclimation fish were planted directly into the Muddy River. In December 2015, the infiltration gallery and water supply control structure to the pond were heavily damaged due to high water. After a site visit and information provided by the Gifford-Pinchot NF Staff on July 14, 2016, the ACC decided that the Muddy River Site would be decommissioned. No fish were ever stocked into this pond.

[1] During their June 2015 meeting, the ACC agreed that releasing acclimation fish earlier in the fall is a better strategy and more akin to the natural out-migration behavior that has been observed in the upper basin. It was also determined that fish released in the fall would be held a shorter amount of time in the hatchery and thus less susceptible to disease (i.e., Bacterial Kidney Disease – BKD) that has been observed in previous years.

- *Clear Creek Acclimation Pond* – Maintaining adequate inflow and pond elevation has been the largest challenge for this site. During spring 2014, approximately 9,000 smolts were stocked in to the Clear Creek Pond, however all fish were released the following week due to low river conditions and reduced inflow. In August 2015, rip-rap was added along the shore near the intake largely improve the structural integrity of the intake structure, but it was also thought to improve inflow. However, similar to the Muddy River Site, the Clear Creek Acclimation Pond sustained heavy damage during the December 2015 high water event. PacifiCorp in coordination with the ACC are in the process of deciding the future of this site.

- *Crab Creek Acclimation Pond* – This site has not been used since its completion in fall of 2015. The Crab Creek site was designed and permitted for spring rearing and release of fish. Fall releases may be difficult at this site due to the hydraulic regime of Crab Creek, which may limit the timeframe in which smolts may be held. PacifiCorp in coordination with the ACC are in the process of deciding the future of this site.

Because of the challenges faced with the holding ponds, the vast majority of acclimation fish have been directly released near the acclimation sites, but not held in the ponds. Since 2012, approximately 355,000 spring Chinook have been directly released into the upper basin (Table 1). All of these releases have been done using a large capacity fish hauling truck and releasing approximately 9,000 to 12,000 fish per load over a short period of time (1-2 days). Overall, information regarding the effectiveness of these releases is largely unknown. Data from PIT tag detections (USGS Crab Creek site) and downstream collection numbers at the Swift Floating Surface Collector suggest that a large portion of these fish move out of the upper basin into the reservoir relatively quickly[2]. Additional information on the residency time following release particularly for fish released during the fall would be helpful for directing future release strategies for the program as well as help make decisions regarding the future of the remaining acclimation sites.

## Planting Schedule and Evaluation Plan (2016)

*Overview*

A total of approximately 34,000 acclimation Chinook are scheduled for direct release in fall 2016 (Table 1). Rather than releasing all these fish in large numbers over a short period of time, it is proposed a proportion of these fish be released in smaller groups over a slightly longer time frame this fall. It is thought that by decreasing the number of fish stocked per planting event, smolts may stay in the system longer and move downstream at a slower rate due to decreased

[2] Detection histories collected at the confluence of Crab Creek in spring 2013 indicated that approximately 60% of tagged acclimation Chinook emigrate within the first seven days following release and 98% within 60 days. Observations at the Swift Floating Surface Collection have noted the arrival of acclimation fish as early as four days after release.

densities. Releasing fish over a slightly longer timeframe will also allow for evaluation of whether timing of release affects residency time for fish released in the fall. That is, do fish released earlier in the fall remain in the tributary streams longer than those released later?

By utilizing a number of Passive Integrated Transponder (PIT) tag antennas presently located in the upper basin, downstream passage of these smaller groups can be monitored. Detection histories will be summarized to determine residency time upstream of the monitoring arrays for each release group. The data collected from PIT interrogations at each antenna will allow for biologist to infer the migration behavior of smolts post-release. These data will help determine the length of time in which smolts resided in their respective system, mean length of time spent in the system prior to outmigration, and whether there are significant differences in residence time among different plantings (i.e., date, system). The 2016 effort will be considered a pilot study and could be used to guide future evaluations designed to assess strategies for acclimation fish releases.

**Table 1. A summary of spring Chinook releases as part of the Lewis River acclimation program since 2012.**

| Species | Brood Year | Plant Date | Number | Size (F/LB) | Plant Site |
|---|---|---|---|---|---|
| *CK:SP* | *2015* | *N/A* | *34,090* | *44.5* | *N/A* |
| CK:SP | 2014 | 10/21/2015 | 14,739 | 23.3 | Crab Cr |
| | | | 33,261 | 23.3 | Clear Cr |
| CK:SP | 2013 | 3/3/2015 | 37,022 | 20.0 | Crab Cr |
| | | 3/4/2015 | 72,644 | 20.0 | Clear Cr |
| CK:SP | 2012 | 10/7/2013 | 16,200 | 23.2 | Crab Cr |
| | | 4/23/2014 | 18,416* | 10.3 | Clear Cr |
| | | 4/23/2014 | 21,012 | 10.6 | Muddy R. |
| | | 5/1/2014 | 44,000 | 10.5 | Clear Cr |
| CK:SP | 2011 | 10/19/2012 | 15,440 | 23.0 | Crab Cr |
| | | 4/1/2013 | 17,655 | 12.5 | Muddy R. |
| | | 4/1/2013 | 13,665 | 12.5 | Clear Cr |
| | | 4/3/2013 | 18,560 | 13.5 | Clear Cr |
| | | 4/3/2013 | 18,560 | 12.2 | Muddy R. |
| | | 4/4/2013 | 14,256 | 12.0 | Crab Cr |

**Note: Includes approximately 9,000 smolts released into the Clear Creek acclimation pond.*

*Methods*

Five upper basin locations will be used as release sites during the fall of 2016 effort. These locations are (Figure 1):

1. Clear Creek Bridge;
2. Upper Muddy River just upstream of the Smith Creek confluence;
3. Muddy River Bridge;
4. Drift Creek Bridge; and
5. Lewis River Bridge at Crab Creek

Acclimation fish will be released at each location beginning the first week of September, through mid-October (Table 2). Smolts will be released bi-weekly to minimize the effects of overcrowding within the release streams. Four groups of approximately 1,000 smolts each will be released at both the Clear Creek and Muddy River sites for a total of about 4,000 fish released. At the Drift Creek release site, four groups of about 500 fish each will be released for a total of 2,000 smolts. Drift Creek will receive fewer fish than the other two test sites due to its smaller overall size. The remainder of the smolts (23,000) will be considered surplus and be released at the Upper Lewis River Bridge at Crab Creek (15,000) and at the Muddy River Bridge (8,000) in a single group in early September (Table 2).

Approximately 25 percent each release group will be tagged with PIT tags and all tag codes will be identified for each group (Table 2). All fish will be tagged in the belly between the posterior tip of the pectoral fin and the anterior point of the pelvic girdle using methods outlined in CBFWA (1999). All tagged fish will be randomly selected and measured to fork length (mm); it is anticipated that fish will range in size from 90 mm to 160 mm. Tagged smolts will be held a minimum of 24 hours to fully recover and assess any delayed mortality before being released.

Downstream passage of PIT tagged fish will be monitored utilizing existing detection arrays located at the confluence of Clear Creek and the Muddy River, the confluence of the Muddy River and Lewis River, and lower Drift Creek (Figure 1). No detection array will be placed in the Lewis River due to logistical constraints associated with installation and maintenance, as well as expected low detection efficiency (consequently, no fish released in the upper mainstem Lewis River will receive PIT tags). All detection arrays will be downloaded weekly. Beacon tags will be used to monitor detection array operation and identify any outages.

**Figure 1. Location of Muddy River, Clear Creek, Lewis River (Crab), and Drift Creek release site(s) and PIT antennae arrays.**

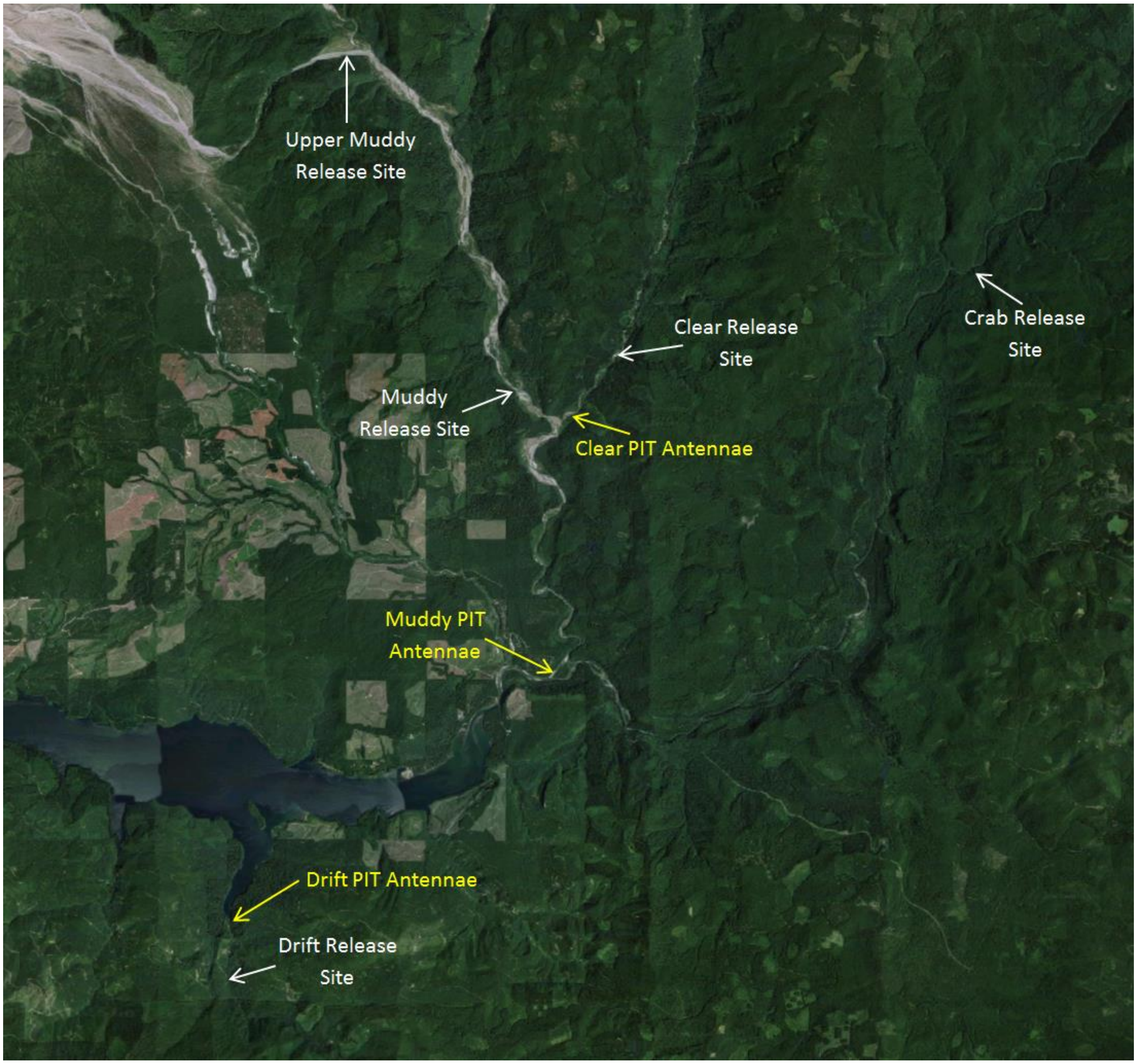

**Table 2. Proposed 2016 Spring Chinook smolt release schedule for the five upper Lewis River Release sites. Number of PIT tagged fish within each release group is shown in parentheses.**

| Period | Muddy River | Clear Creek | Crab Creek | Drift Creek | Total |
|---|---|---|---|---|---|
| Sept. 5-9 | 1,000 (250)<br>Upper Site<br><br>8,000 (500)<br>Bridge Site | 1,000 (250) | 15,000 (0) | 500 (125) | 2500 |
| Sept. 12-16 | 0 | 0 | 0 | 0 | |
| Sept. 19-23 | 1,000 (250)<br>Bridge Site | 1,000 (250) | 0 | 500 (125) | 14000 |
| Sept. 26-30 | 0 | 0 | 0 | 0 | |
| Oct. 3-7 | 1,000 (250)<br>Upper Site | 1,000 (250) | 0 | 500 (125) | 14000 |
| Oct. 10-14 | 0 | 0 | 0 | 0 | 0 |
| Oct. 17-21 | 1,000 (250)<br>Bridge Site | 1,000 (250) | 0 | 500 (125) | 2500 |
| **Total** | **12000 (1500)** | **4000 (1000)** | **15000 (0)** | **2000 (500)** | **33000 (3000)** |

Date, time of day, and tag code will be stored for each detection. Detection data for each release group will be summarized across the monitoring period at each site. Residency time upstream of each monitoring site will be calculated for each tagged fish as the difference in date/time between release and detection downstream. To decrease the influence of outlying data points, upstream residency time will be evaluated based on median as opposed to mean time. Comparisons of median upstream residency time among release groups will be made using a standard median test (Conover 1999). Date of release, PIT interrogations at the antennae arrays, and date that tagged smolts are recaptured at the FSC will also be used to estimate residence time in Swift Reservoir.

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**MEMO**

**2016 Spring Chinook Acclimation Planting Schedule and Evaluation – Summary of Results**
Prepared by PacifiCorp
January 20, 2017
***Final***

This memo provides a summary of findings related to the 2016 Spring Chinook Acclimation Planting Schedule and Evaluation Plan, which was approved by the Aquatic Coordination Committee (ACC) during the August 11, 2017 meeting. The methodologies outlined in the approved plan were followed, however some modification were made due to slightly lower than anticipated fish numbers and site access and flow conditions.

A total 29,900 juvenile spring Chinook were available for release in fall 2016 (34,000 were anticipated). Releases occurred from mid-September through mid-October with a proportion of each release group tagged with PIT tags (Table 1). Unfortunately, the initial release groups were tagged with full duplex (FDX) PIT tags which were not compatible with the upper basin detection arrays. This was not discovered until after the initial release groups were tagged. The remaining release groups were tagged with the compatible half-duplex (HDX) PIT tags. Consequently, samples sizes were adjusted to maximize releases at Clear Creek and Muddy River Sites (bridge-site only). Detection arrays located at the Swift Floating Surface Collector were used to monitor passage timing of smolts released with FDX PIT tags.

**Table 1. Summary of Spring Chinook acclimation releases during fall of 2016.**

| **Period** | **Clear Creek** | **Muddy River** | **Crab Creek** | **Drift Creek** | **Total** |
|---|---|---|---|---|---|
| Sept. 12-16 | 8,000 (500 FDX) | 0 | 15,000 | 500 (100 FDX) | 23,500 (600 FDX) |
| Sept. 19-23 | 0 | 2,300 (2300 FDX) Bridge-Site | 0 | 0 | 2,300 (2300 FDX) |
| Sept. 26-30 | 1,850 (300 HDX) | 1,850 (300 HDX) Bridge-Site | 0 | 0 | 3,700 (600 HDX) |
| Oct. 3-7 | 0 | 0 | 0 | 0 | 0 |
| Oct. 10-14 | 200 (200 HDX) | 200 (200 HDX) Bridge-Site | 0 | 0 | 400 (400 HDX) |
| **Total** | 10,050 (500 FDX, 500 HDX) | 4,350 (2400 FDX, 500 HDX) | 15,000 | 500 (100 FDX) | 29,900 (2900 FDX, 1000 HDX) |

Two groups of smolts containing HDX PIT tags were released at both the Clear Creek and Muddy River sites (Table 1). However, the second groups (released in mid-October) occurred just prior to a high water event that washed out the PIT tag antennas shortly after release (< 1 day). Therefore, detection information was unavailable for making inferences on residency timing of acclimation fish.

*Clear Creek Releases*

Approximately 1,850 smolts were released on September 28, 2017; of these fish, 300 were PIT tagged. A total of 89 of the 300 PIT tagged smolts were detected at the downstream Clear Creek antenna. Median residency time was 19.75 hours. Approximately half (51%) of PIT detections occurred within the first 24 hours following release. Detections began approximately 10.6 hours after release, and the last detection occurred 205.8 hours post-release.

The second release was made up of 200 smolts, all of which had been PIT tagged. The second release was made on October 12, 2017. Residency timing analysis could not be performed for the second release, as the antenna was blown out in a high flow event less than 24 hours after the release took place.

**Table 2. Detection summary for PIT fish released in Clear Creek during 2017.**

| Spring Chinook Releases | Number Tagged | Number Detected | Median Detection Time |
|---|---|---|---|
| Release 1 (September 28, 2017) | 300 | 89 | 19.75 |
| Release 2 (October 12, 2017) | 200 | N/A* | N/A* |

**High flows washed antenna out immediately following second release.*

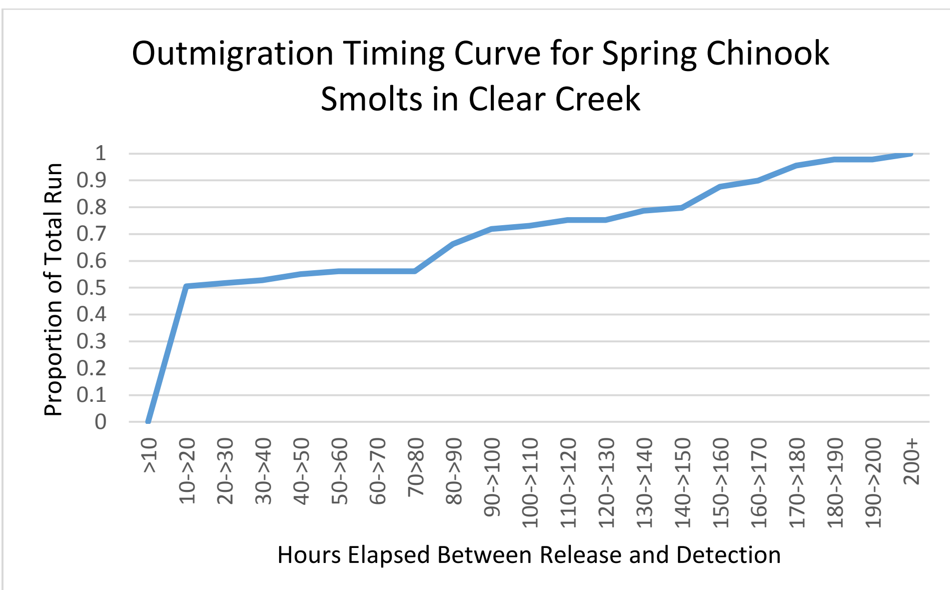


**Figure 1. Outmigration timing curve of Spring Chinook Smolts following their release into Clear Creek on September 28, 2016.**

*Muddy River Releases*

Approximately 1,850 smolts were released into Muddy River on September 30, of which 300 had been PIT tagged. A total of 125 of the 300 PIT tagged smolts were detected at the downstream antenna. Median residency time for this release was 17.06 hours. Detection times ranged from 9.3-115 hours following release. However, approximately 2/3 (65.6%) of the PIT interrogations occurred within 24 hours of release.

The second release consisted of 200 PIT tagged smolts, and took place on October 13. Data from this release was unavailable, as a high flow event disabled the in-stream antenna.

**Table 3. Detection summary for PIT fish released in Muddy River during 2017.**

| Spring Chinook Releases | Number Tagged | Number Detected | Median Detection Time |
|---|---|---|---|
| Release 1 (September 30, 2017) | 300 | 125 | 17.06 |
| Release 2 (October 13, 2017) | 200 | N/A* | N/A |

**High flows washed antenna out immediately following second release.*

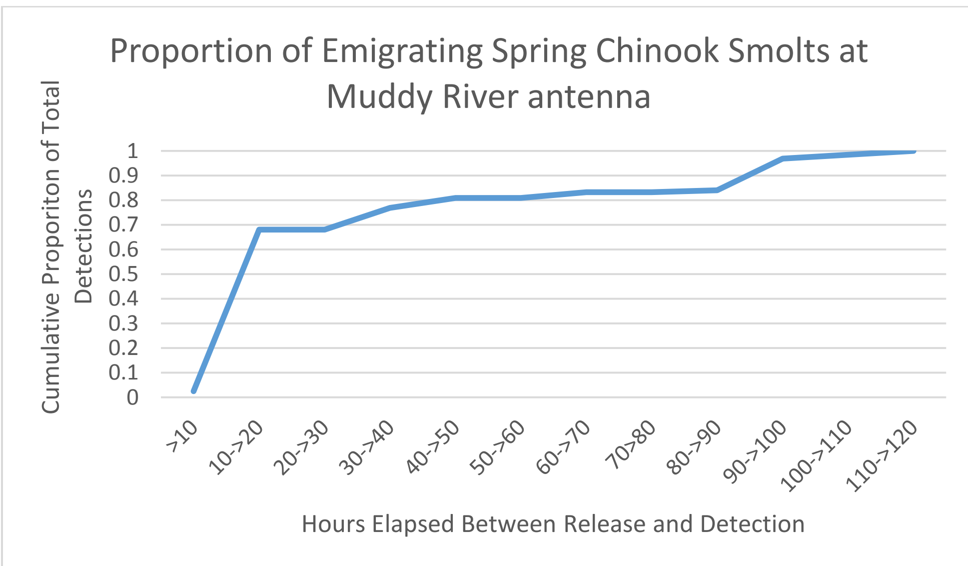


**Figure 2: Outmigration timing curve of Spring Chinook smolts following their release into the Muddy River on September 30, 2016.**

*Discussion*

While various factors reduced the scope of this study compared to what was originally intended, information from the PIT tag detections indicate that at least a proportion of smolts released directly into the upper basin move downstream immediately following release. The general migration pattern for both systems was very similar during the September releases, with about 50-60% of the detections occurring less than 24 hours following release. In both the Clear Creek and Muddy River systems, detections began shortly after release (10.6 and 9.3 hours post-release, respectively), and both had median residency times of just under 20 hours. Similar outmigration patterns characterized by relatively rapid downstream movement immediately following direct release were observed by USGS for juvenile spring Chinook released into Clear Creek in 2014 (PacifiCorp 2016) .

While the vast majority of detections occurred just shortly after release, overall detection of tagged fish was less than 50% (only 30% of the smolts released into Clear Creek were detected and only 42% of smolts released in the Muddy River were detected). This could indicate that a proportion of fish remained upstream of the detection site over the period in which the antenna was in place. In both systems, there appeared to be an initial push of fish immediately following release followed by smaller numbers of fish out-migrating over a relatively longer period of time (up to a week). Another possible explanation to this observation, however, is that both antennas experienced very low detection efficiency immediately following release when a larger number of PIT tagged fish migrated past. Having multiple tagged fish in the detection field can result in tag collision, in which the PIT tag reader is unable to accurately log the tag number. Because a large number of smolts passed the antenna over a relative short amount of time, it is possible that a high proportion of the tagged fish were simply missed.

Given the relatively truncated timeframe in which data was collected, combined with low detection efficiencies, no conclusive recommendations can be made from this year's direct-release strategy. Observation made during the 2016 releases were generally consistent with those previously observed for juvenile spring Chinooks released directly into the river in the upper basin. Future detections of smolts released as part of this evaluation at the Swift Floating Surface Collector (FSC) may provide additional information on smolt residency time when compared with detection histories in the upper basin. However, low collection efficiencies of spring Chinook at the FSC likely limit a robust analysis.

PacifiCorp. 2016. New Information Regarding Fish Transport into Lake Merwin and Yale Lake *in* Task 4: Assessment of Juvenile Production and Outmigration Success. Prepared for PacifiCorp

## APPENDIX B

## SWIFT RESERVOIR FLOATING SURFACE COLLECTOR SMOLT COLLECTION EFFICIENCY EVALUATION – 2016 REPORT

# SWIFT RESERVOIR
# FLOATING SURFACE COLLECTOR
# JUVENILE SALMON COLLECTION EFFICIENCY

## 2016 Annual Report - FINAL

*Prepared for:*

PACIFIC POWER
A DIVISION OF PACIFICORP


*Prepared by:*

Lucius Caldwell, Dana Stroud, Forrest Carpenter, Lindsey Belcher, Kai Ross, and Kevin Ceder


January 23, 2017

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# ACKNOWLEDGEMENTS

Thanks to Nancy Christensen (ATS) for her help with acoustic telemetry (AT) receiver design, and to the Advanced American Construction, Inc., team for assistance with AT deployment.

# EXECUTIVE SUMMARY

This report describes results from the fourth year of a study designed to quantify the collection efficiency ($P_{CE}$) of a new, state-of-the-art, floating surface collector (FSC). The FSC was designed to collect outmigrating juvenile salmonids from Swift Reservoir, on the North Fork of the Lewis River, Washington. Operation of the FSC began in December 2012. This report summarizes the results of a telemetry study designed to address Section 2.2 of the Lewis River Aquatic Monitoring and Evaluation Plan (hereafter "M&E Plan"; PacifiCorp and Cowlitz PUD 2016), regarding passage of out-migrating juvenile steelhead (*Oncorhynchus mykiss*), spring Chinook (*O. tshawytscha*), and coho (*O. kisutch*) smolts through Swift Reservoir and ultimately around Swift Dam. The M&E Plan outlines the need to quantify $P_{CE}$ for the Swift Reservoir FSC, and defines a goal of 95% for juvenile salmonids that are available for collection.

The primary goals of the 2016 Swift Reservoir out-migration study were twofold: 1) determine $P_{CE}$ for coho, spring Chinook, and steelhead smolts at the FSC; and 2) evaluate how out-migrating smolts interact with the newly installed FSC guide net that was hypothesized to bolster orientation of smolts toward the FSC and thus increase $P_{CE}$. In addition to these core goals, in this report, we also explore factors hypothesized to underlie $P_{CE}$ at the Swift Reservoir FSC through logistic regression and visual analysis.

For the 2016 study, after methods outlined in Section 2.2 and recommendations made from the 2014 and 2015 studies (Reynolds et al. 2015; Stroud et al. 2014), as many coho, spring Chinook and steelhead smolts as possible were captured from the screw trap located at Eagle Cliff or hook-and-line captured from the upper reservoir. Remaining fish were captured at the FSC to bolster sample sizes. All fish were dual tagged with acoustic telemetry (AT) and passive integrated transponder (PIT) tags, released at the head of Swift Reservoir, and then monitored using an autonomous AT array designed to detect fish as they made their way back downstream towards the FSC.

In total, 205 smolts were dual tagged and released. Following a quality-assurance (QA) process, records associated with 199 smolts were retained in the study for subsequent analysis. Of these 199 fish, 88% were detected within the AT array, 84% were detected in the forebay (non-shoreline AT receivers), 58% were detected in the Zone of Influence (ZOI) and 17% were ultimately captured by the FSC for passage around the dam. $P_{CE}$ across all species was relatively low: 29% of the fish detected in the ZOI were subsequently captured by the FSC. Approximately 80% of captured smolts were collected before the 7DADA water temperatures in Swift Reservoir reached 15°C, and 99% of all fish passed before 7DADA water temperatures in Swift Reservoir exceeded 16°C.

Network theory was applied to visualize and analyze fish movements in front of the FSC to infer behavior when fish interacted with the newly installed guide net. Our analysis suggests that the fish did not interact extensively with the guide net during 2016. While fish may have ultimately been redirected by the guide net, the tracking data do not indicate a strong behavioral response, *i.e.*, consistent directional movement towards the FSC upon encountering the guide net. It may be the case that smolts sound underneath the net, but equally likely is the possibility that, upon encountering the net, fish initially swim away from the FSC. Most fish were detected in the forebay between the receivers directly in front of the FSC (NW, NE, SW, SE). The most frequent

pathway that resulted in an ENT detection came from SWF→NW→ENT, suggesting that fish tend to approach the ZOI from the northern portion of the forebay more often than from the south. These results are inconsistent with those found the previous year (2015) when the guide net was not installed. The ultimate reasons for this difference between 2016 and 2015 results (when fish appeared to approach more often from the south) is difficult to resolve, and may reflect differences due to hydrologic or other environmental conditions, operations, or the guide net itself. The majority of milling tended to occur at SE, NW and SW receivers whereas the majority of holding appeared to occur at NSH and SSH receivers.

We employed logistic modeling approach to quantify the effects of independent factors on the likelihood of FSC capture of out-migrating smolts. Primary contributing factors that led to a fish passing successfully at the FSC include the following: Capture Location, Species, Release Day, Reservoir Residence Time, and Fork Length. Fish captured at the FSC have the lowest proportion of recaptures of all methods. Coho and steelhead have higher recapture rates than Chinook, although this could be an artifact of low sample size for Chinook. Fish that are tagged and released before May 26 appear to have a slightly higher probability of being recaptured than those tagged and released after this date. Fish that spend less time in the reservoir (calculated as the difference between the tagging date and the final AT detection date) have higher probabilities of being recaptured. Of the variables included in the reduced model, those with the strongest effect on collection rates were release day, reservoir residence time, and species. The remaining variables included in the reduced model tended to have relatively small (though significant) effects on collection rates; taken together, the model correctly predicted recapture or no recapture 85% of the time and misclassified around 15%.

We have a number of recommendations that emerged from the current analysis, including the following:

1) Install one or more networked PIT tag reader(s) at the FSC or begin a routine clock-checking process and log on a regular and frequent interval.

2) Focus capture efforts on and before May 26$^{th}$. Exert the majority of capture effort using hook and line capture and/or at the Eagle Cliff RST rather than using non-naïve fish that have been previously captured at the FSC.

3) After non-target study species are caught at the FSC, adopt a policy of manually checking these fish for PIT (and AT if possible) tags prior to release back into the reservoir (*e.g.*, did a large hatchery rainbow trout or bull trout consume a tagged smolt that should be removed from the study?).

4) Consider implanting archival tags that include pressure sensors in order to more finely resolve fish behaviors near the guide net, which could inform infrastructural changes in improve $P_{CE}$ and optimize smolt collection efficiencies.

# INTRODUCTION & SUMMARY OF PREVIOUS MONITORING EFFORTS

The Swift Reservoir Floating Surface Collector (FSC) is a floating barge (15.2 x 6.0 x 2.4 meters) equipped for collecting and handling out-migrating fish, typically juvenile salmon and steelhead, and adult steelhead (kelts), which are ultimately transported around Swift Dam. The FSC is located near the south end of the Swift Dam, adjacent to the turbine intake and spillway. Attached to the front of the FSC is an independently floating structure called a Net Transition Structure (NTS), with barrier nets that extend to either shoreline to prevent fish from going past the FSC and entering the turbine intake (Figure 1). Pumps onboard the barge generate positive flow within an approximately 46m (150 ft) radius upstream of the FSC; this area is defined as the Zone of Influence (ZOI) (PacifiCorp and Cowlitz PUD 2016). Emigrating fish that enter the ZOI tend to be attracted, and ultimately swim into the FSC, approaching via an artificial stream channel that guides fish from the NTS into the FSC for safe transport downstream.

In 2013, a pilot study (Courter et al. 2013) demonstrated the feasibility of implementing a radio telemetry array to assess passage rates and fish behaviors in the study area. Due to failure of an exclusion net that allowed large numbers of smolts to access the area behind the FSC, the observed frequency of capture at the FSC (*i.e.*, capture efficiency, $P_{CE}$) could not be calculated in 2013. Nonetheless, valuable insights emerged from the pilot study, leading to the following operational changes:

1) Removal of the mooring tower receiver station,
2) Addition of receiver station at the north and south shorelines at the entrance of the forebay, and
3) Reduction of the radio tag burst from seven (7) seconds to five (5) seconds.

In 2014, a second year of the study was undertaken, in which salmon and steelhead smolts were captured at the FSC, and either surgically (55%) or gastrically (45%) implanted with Lotek radio tags, held for one (1) day, and then released upstream, approximately 3.2 km (2 mi) east of the FSC. In 2014, collection efficacy ($P_{CE}$) across all species was 26.3% (Stroud et al. 2014). Low capture rates observed in this year were thought to be due to one or more of the following:

- tagging effects,
- fish stress,
- release location (mid-reservoir)—hypothesized to result in increased predation—or
- prior FSC exposure (*i.e.*, non-naïve fish that avoided a repeat capture event).

During the 2014 study, to test the hypothesis that prior FSC exposure would result in a lower $P_{CE}$, a subset of individuals (n=8) that had not been previously captured at the FSC were tagged and then released upstream of the reservoir (14.5 km (9 mi) east of the FSC). $P_{CE}$ rates were compared between the two groups of naïve and non-naïve individuals. Although sample sizes were low, the proportion of fish detected in the reservoir ($P_{RES}$) improved by over 300% for the naïve individuals. Approximately 88% of fish (7 of 8) that were released at the rotary screw trap (RST) near the head of the reservoir at Eagle Cliff (i.e., naïve fish) were subsequently detected in the forebay. This was substantially higher $P_{RES}$ than was observed for non-naïve fish collected from the FSC and placed back into the reservoir (*i.e.*, 88% detection vs. 19.7% detections for all other fish).

In 2015, there were several major changes to the study design intended to develop inference regarding causative factors driving $P_{CE}$ rates in the reservoir:

- The experimental design was changed from using radio tags to using autonomous acoustic receiver arrays
  - *Implication*: Detection ranges vary between years.
- Study fish were surgically tagged with a different type of transmitters
  - Previously used Lotek RT transmitters with an approximately 5 sec second ping rate with SRX-400 receivers and switched to JSATS acoustic transmitters; approximately 5 second ping rate with SR3000 Trident ATS receivers.
- A majority of 2015 study fish were captured from the RST at Eagle Cliff.
- Tagged fish were released at the head of the reservoir on the south shore opposite of Swift Forest Camp.

In 2015, a majority of tagged out-migrating salmonid smolts (all species) made a first pass through the AT array approximately 200 – 450 ft from the FSC. Fish approached the FSC from the south 66% of the time; fish that initially entered the forebay from the north shore swam to the south shore before re-orienting north and then moving towards the entrance.

Overall, the switch from radio telemetry (RT) to AT in 2015 enabled inference of fine scale movements of out-migrating smolts and the factors driving $P_{CE}$ while still allowing for the calculation of the proportion of tagged fish that entered the ZOI and that were subsequently collected by the FSC (a requirement of the Federal Energy Regulatory Commission). In 2015 the $P_{CE}$ rate across all species was 13.2% (Reynolds et al. 2015).

In 2016, CFS repeated the autonomous acoustic receiver array design, with the following adjustments to the array:

1) The CUR (located near the south extent of the barrier net and adjacent to the shoreline) receiver was removed and SWF (located in the Swift Creek arm of the forebay) was added to make inference about fish use in Swift Creek Arm; and
2) A guide net was installed on the front of the FSC.

These additional changes are fully described in the *Data Collection*

*Acoustic* Telemetry Design section of this report.

For the current year, (2016), the primary objectives of study were as follows:

1) Determine passage efficiency for salmonid smolts out-migrating through Swift Reservoir via the FSC, and
2) Evaluate how out-migrating smolts interact with the newly installed FSC guide net.

Based on previous findings and anecdotal reports of delayed migration, we also hypothesized that fish passage around Swift Dam depends upon water temperature within Swift Reservoir.

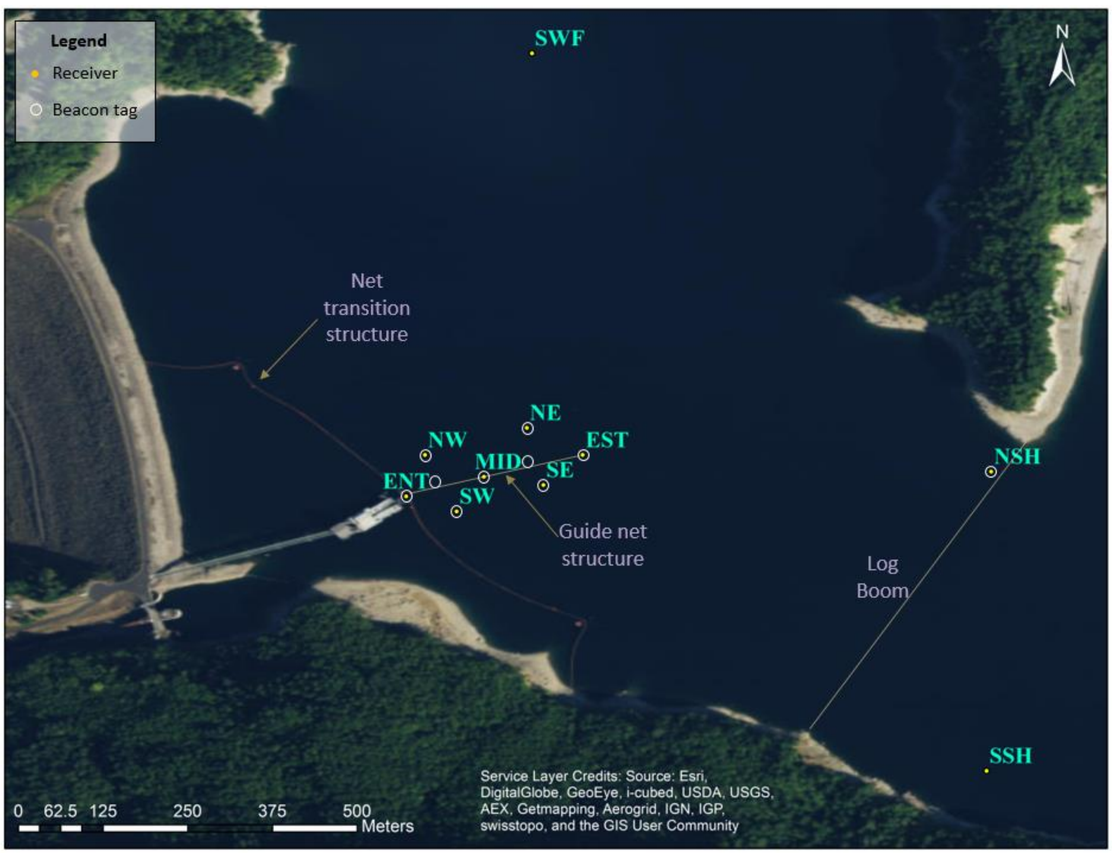
Above a threshold temperature, the balance may switch between fish actively emigrating and fish returning upstream to the river and delaying migration for another year. A body of evidence indicates that juvenile salmonids exhibit behavioral thermoregulation in response to warm temperatures: individual fish actively control their depths and swimming behaviors (Adams et al. 2015; Armstrong et al. 2013; Eckmann 2015; Plumb et al. 2014). Because individual temperature histories experienced by both successful and unsuccessful out-migrating smolts were not available (*i.e.*, as could be obtained using temperature-sensing data-transmitting tags), inclusion of temperature within a predictive model is not logically appropriate. Consequently, we omitted reservoir temperatures from our model and instead visually explored the relationship between reservoir water temperature and smolt passage timing at the FSC. Below, we explore a suite of additional factors hypothesized to influence successful passage (and thus underlie $P_{CE}$) at the Swift Reservoir FSC.

# METHODS

## Study Site

In response to the findings from PacifiCorp's 2015 study (Reynolds et al. 2015), prior to the 2016 monitoring effort, a 650 ft (198 m) long guide net reaching 60 ft (18 m) deep was installed off the upstream end of the FSC, projecting into the Swift Dam forebay. Two receivers and two beacon tags were attached to the guide net (receivers: MID and EST; beacon tags: E and W; Figure 1). The guide net was installed with the goal of intercepting fish that were traveling along a south to north path hypothesized to be following a forebay gyre, and help direct them towards the attractive flow near the entrance of the FSC.

A log boom spanning the reservoir from the Devil's Backbone to the south shore was also installed in response to high amounts of debris and large wood accumulating at the front of the FSC and along the newly installed guide net. The log boom was placed in operation in April 2016[1]. When the log boom was in operation, the NSH receiver was attached directly to the boom structure. Before the log boom was placed in operation, the NSH receiver was freestanding with an anchor-buoy system, similar to the other receivers in the AT array.




[1]Boom was removed at the end of May 2016 on account of temporary permitting limitation. The boom was permanently permitted and reinstalled in November 2016.

Figure 1. Diagram of the receivers and beacon tags deployed in the uppermost Dam on the Swift Reservoir on the Lewis River. At the southwest corner of the reservoir is the Floating Surface Collector which traps out-migrating fish as they move downstream.

# Data Collection

## *Acoustic Telemetry Design*

During Spring – early Summer 2016, ten (10) autonomous AT receivers were deployed within the forebay of Swift Reservoir (Figure 1) in an array designed similarly to that used in 2015 study. In order to determine how fish approached the forebay and eventually transitioned to the FSC, both north shore (NSH) and south shore (SSH) receivers located at the Devil's Backbone (which naturally delineates the entrance to the Swift Dam forebay) were retained. Seven (7) receivers were deployed directly upstream (in front) of the FSC in a similar "double-diamond" configuration with the long axis perpendicular to the face of the Net Transition Structure (NTS). A single receiver was deployed at the entrance to FSC (receiver ENT) and served to define the ZOI.

Two minor adjustments were made to the design of the array based on results from 2015:

1) To assess the frequency at which smolts moved past the FSC and towards Swift Creek Arm, the receiver which previously had been located on the south end of the NTS curtain (receiver CUR in 2015) was moved and placed instead immediately north of the FSC. This receiver was renamed SWF for 2016. Double diamond shaped receivers were installed in the inlet to the west of Devil's Backbone (Swift Creek arm).
2) A guide net was installed along the front of the FSC, and receivers were placed along its length in order to test the hypothesis that this structure would result in higher collection efficiency of out-migrating smolts.

In addition, beacon tags were deployed in tandem with each AT receiver to determine the integrity of the detection record associated with each receiver in the array by providing a continuous record of detection. When a beacon log was not detected by a given receiver, this suggested that other transmitters (*e.g.*, tags that had been implanted inside of fish) would not be detected at this location. Ten (10) beacon tags were deployed in 2016: One (1) beacon tag was placed at the center of each of the double diamond receivers (ENT, SW, NW, MID, SE, NE, EST), plus each receiver, except SWF and SSH sites, was equipped with a beacon tag.

Under ideal conditions, the SR3000 AT receivers are reported to have a maximum detection range of 100 m (328 ft) (Trident 2013); however functional ranges during preliminary range tests performed in 2015 suggest 30 – 50 m (98 – 164 ft) detection zones (Reynolds et al. 2015). A fixed PIT antenna was used to detect fish after they entered the sorting building on the FSC and were successfully collected for passage.

Due to the concern that the relatively fine mesh on the guide net would interfere with the ability of the receivers to detect fish, the MID and EST receivers were placed at approximately 21 m (69 ft) depth, whereas the other receivers were placed at approximately 6 m (20) depth. Per recommendations from Advanced Telemetry Systems, Inc., hydrophone nipples were oriented downwards. This setup provides an approximately conical 100 m (328 ft) radius of effective detections around each receiver, with an orb of no-detection immediately below the hydrophone receiver.

PacifiCorp completed three separate manual tracking exercises within Swift Reservoir to help address post-release mortality and predation. Surveys were done by deploying an SR3000 Trident acoustic hydrophone behind a boat and watching a live feed of the hydrophone's readings. Detected tags were then recorded by their tag code and reservoir location. During each survey, the entire forebay and head of the reservoir were monitored along with six reservoir cross sections of equal distance apart and each tributary cove. Manual tracking data were then analyzed for tag codes remaining in the same position over several survey periods (signifying a possible post-release mortality) or tag codes remaining around the Eagle Cliff area (signifying predation by bull trout or hatchery rainbow trout). These two methods (PIT tagging and manual tracking) were done to generally inform or alert CFS and/or PacifiCorp personnel to any underlying problems associated with tag failure, tag loss, decay rate, post release mortality or predation. Exact quantities were not calculated. Rather, if data suggests an underlying problem with tag failure, predation etc. exists then future studies will need to include fish holding capabilities to perform a paired holding study.

## *Fish Condition and Tagging*

Tagging methods for 2016 followed previously described protocol (Reynolds et al. 2015), with the exception that, whereas in 2015 approximately 75% of tagged fish were collected at the RST near Eagle Cliffs (Reynolds et al. 2015), during the current year (2016) low numbers of fish were collected at the RST, and a majority of tagged fish were collected at the FSC.

Due to a lack of the type of facilities outlined in Section 2.2 of the M&E Plan for performing a paired holding study (*i.e.*, small circular raceways with adequate long-term holding environment), it was not possible to quantify acoustic tag failure, loss, or decay rate, or post-release fish mortality. Instead, all fish collected for the 2016 study were double tagged with one (1) PIT tag and one (1) acoustic tag, forming a unique pair of PIT/acoustic tag codes for each fish. Subsequently, two (2) methods (PIT tagging and manual AT tracking) were undertaken to inform estimate tag failure, tag loss, decay rate, post release mortality or predation.

The FSC contains PIT tag arrays that, at the time of capture at the FSC, detect and record unique identifying codes associated with PIT tags previously implanted in fish. To address tag failure, tag loss and decay rate, PIT tag records at the FSC were compared to acoustic tag records within the forebay and FSC entrance. If a PIT tag was recorded (indicating capture in the FSC) but no AT detections were recorded, then it was inferred that the acoustic tag in that fish presumably failed or was lost from the body cavity (*e.g.*, via tag encapsulation), or that the tag battery power had catastrophically declined (*NB*: expected battery life was approximately 30 d, with a constant ping rate of 5 seconds or $12 \cdot \text{minute}^{-1}$).

In addition, to evaluate the number of acoustic tagged fish that were detected in the upper portion of the reservoir, and to determine if there were any fish that appeared stationary (which would suggest tag loss or mortality), PacifiCorp completed several manual tracking exercises within

Swift Reservoir. Surveys involved deploying an acoustic antenna behind a boat and driving along a designated route. During each survey, the entire forebay and head of the reservoir and each tributary cove were monitored, and six equally spaced reservoir cross-sections were driven.

### Environmental Conditions

Water temperature was monitored continuously throughout the study by deploying a series of thermistors and data loggers (Hobo® Water Temp Pro v2), affixed along a vertical profile to the mooring tower immediately downstream of (behind) the FSC. Loggers were attached to a mooring line at a fixed elevation (*i.e.*, above sea level, ASL). However, reservoir water levels fluctuated throughout the study, and thus the depth of these loggers varied throughout the course of deployment. Consequently, we used the record of Swift Reservoir surface elevation provided by PacifiCorp to calculate daily averaged depth of each temperature logger as follows:

$$D_{j,i} = E_{Res,i} - E_{j,i} \qquad \textit{Equation 1}$$

Where:

$D_{j,i}$ = estimated mean depth of logger *j* on day *i*

$E_{res,i}$ = mean surface elevation (ASL) of Swift Reservoir on day *i* and

$E_{j,i}$ = elevation (ASL) of logger *j* on day *i*.

## Data management

Weekly AT receiver downloads were combined into a single detection history within a Microsoft MySQL database for subsequent analysis. Prior to collation into MySQL, headers containing data outside of acoustic detections (*e.g.*, data concerning battery status, receiver name, etc.) were removed and stored in metadata files. Additionally, several weekly downloads contained artefactual (nonsensical) rows of characters that were also removed prior to inclusion into the database. All records were reviewed for inconsistencies and were subsequently subjected to a quality assurance (QA) process that involved the following queries:

1. Were any tags released twice or does a fish have more than one PIT tag code?
2. Were there multiple PIT detections for one fish for more time than we would expect given the location of the PIT tag reader (*e.g.*, more than 1 hour)?
3. Were there PIT tag detections >1 year after the PIT tag was implanted into a fish, suggesting that smolts from 2015 were captured in 2016 as delayed migrants?
4. Were there AT detections in the forebay after the fish had been collected at the FSC based on the PIT tag detection timestamp? (See algorithmic approach we used to deal with this situation, under the heading "Detection Timestamp QA Process").
5. Were there AT detections prior to the release time for a given fish?

### Detection Timestamp QA Process

In a modest number of cases (23/205 tag records), based on the associated time stamps generated by the respective receivers, AT receiver detections occurred within the AT array located in the Swift Reservoir *after* the PIT tag receiver detection at the FSC (Figure 2). This is problematic, because a PIT tag detection is assumed to indicate successful capture at the FSC, and removal from the study system: Due to infrastructural and operational logistic constraints (*i.e.*, directionality of facilities and fish handling processes), a free-swimming juvenile salmonid is not capable of being detected within the AT array after being captured (*i.e.*, PIT tag detected) at the FSC. Thus, any AT detection occurring after the PIT tag detection associated with a particular fish is cause for concern. Resolving these discrepancies is important, because enumerating fish captured at the FSC (based on PIT tag detections) forms the basis for inferring fish passage rates.

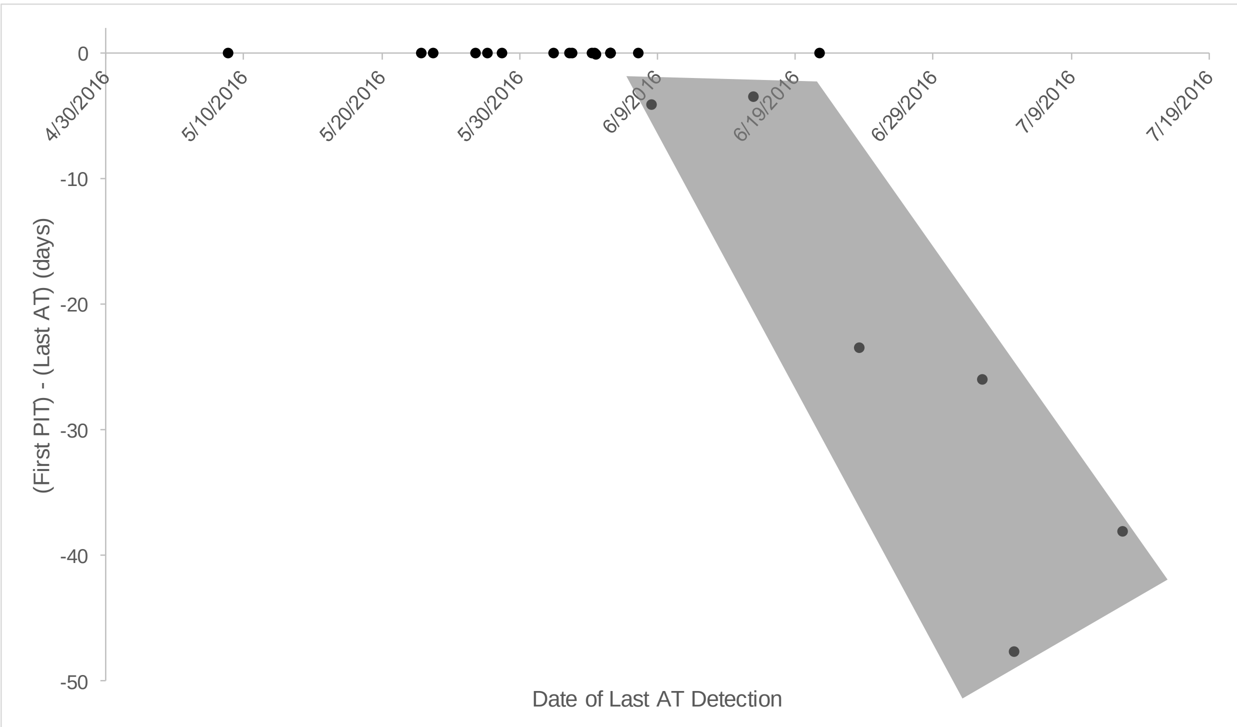



Figure 2. Time series plot of discrepancy between timestamp of first PIT tag detection and timestamp of last AT detection for 23 fish that exhibited AT detections after being PIT tag detected at the FSC. Gray shaded polygon indicates discrepancies >1 day, which may be due to predation or shed tags. Note that 17 of the 23 exhibited modest discrepancies (<150 minutes), and 13 of these 17 exhibited consistent discrepancies of 52 minutes.

In some cases, fish were detected within the AT array for long durations (nearly 48 d) after being PIT tag detected at the FSC. During conversation with PacifiCorp staff, three plausible explanations were suggested:

i. A time stamp discrepancy between the AT receivers (which were all frequently calibrated to a GPS clock) and the PIT tag receiver (which was not calibrated or otherwise adjusted throughout the season),

ii. Predation, *e.g.*, by hatchery rainbow trout frequently observed within and near the FSC, or

iii. Shed tag or tag-containing dead fish re-deposited within the reservoir as part of regular ongoing FSC maintenance including debris-clearing efforts. (*NB: such a tag would presumably be detected only until the tag or fish sunk or otherwise drifted out of range of detection*.)

To determine whether the combined tag detection patterns plausibly suggest reasonable behaviors that could be expected of juvenile salmonids, and to make decisions about which tag records should not be included in analysis (*e.g.*, because data suggest predation or similar loss of free-swimming lifestyle), we applied a quality assurance (QA) algorithm to help determine the following:

A. Whether PIT tag detection time stamps were accurate or should be adjusted, and

B. Whether behaviors inferred from A/T detections are congruous with plausible behaviors of juvenile salmonid approaching and ultimately being captured at the FSC (*e.g.*, do the detections imply an impossible behavior?).

This QA process attempted to rigorously answer the following questions:

1. Does the PIT detection temporally occur between AT detections, implying an unreasonable or unlikely behavior?
2. Do the final AT detections for an individual tag support the hypothesis that the fish in which that tag was implanted was ultimately captured at the FSC?

To address Question 1 and evaluate the likelihood of the first potential source of discrepancy within the tag records (*i.e.*, a possible time mismatch between the AT and PIT tag receivers), we developed a QA algorithm. This algorithm was designed to evaluate the patterns of behavior implied by the extant temporal sequence of AT detections immediately before and after the PIT tag detections (which were taken to indicate capture at the FSC). In other words, we analyzed spatiotemporal components of the AT→PIT→AT records, focusing on the locations of AT detections immediate before ($AT_{pre}$) and immediately following ($AT_{post}$) the PIT tag detection, in addition to the time stamp on each of the preceding and following AT detections ($T_{pre}$ and $T_{post}$, respectively). Within this framework:

- When considering the intermediate PIT tag detection at the FSC, were the preceding and following AT detections at one of the furthest AT receivers?
  - IF $AT_{pre}$ OR $AT_{post}$ = (SWF OR SSH OR NSH), THEN “Unlikely Distance” (UD)
- When considering the intermediate PIT tag detection at the FSC, were the preceding and following AT detections unreasonably far apart to have been traversed by a juvenile salmonid with an FSC detection in between them?
  - IF (($AT_{pre}$ = (ENT OR SW OR NW OR MID)) AND ($AT_{post}$ = (ENT OR SW OR NW OR MID))), THEN “Possible Distance” (PD)
  - IF ($AT_{pre} = AT_{post}$) THEN PD
  - ELSE UD
- Does enough time elapse between the preceding AT detection, the PIT tag detection, and the following AT detections for a juvenile salmonid to reasonably exhibit such swimming behavior?

   - IF ($\Delta(T_{pre}, T_{post})$) < 10 min, THEN “Unlikely Time” (UT)

From the answers to these questions, we applied an algorithmic approach to determining whether we had reasonable confidence that the time stamps on PIT tag detections were not aligned with the time stamps for AT detections, as follows:

- IF (UD OR UT), THEN “1”
- ELSE “0”

A score of 1 was interpreted as evidence supporting a discrepancy between the PIT and AT time stamps, and a score of 0 was interpreted as evidence that does not support a time discrepancy between PIT and AT detection time stamps. The scores across all problematic tag code records were summed to develop a comparative score of evidence “For” and “Against” a time stamp discrepancy. These scores were qualitatively interpreted to arrive at a decision of whether to adjust time stamps on PIT tag detections. Results in the context of Function 1 are described below.
Question 2 was then addressed to develop evidence supporting or refuting the hypothesis that the tag detections reflect behaviors of a free-swimming juvenile salmonid approaching the FSC (*i.e.*, the second and third possibilities [the tag being shed within the FSC or a predation event] suggested to explain the discrepancies temporal sequence of detection histories by PacifiCorp staff), by posing and answering a second series of questions:

- Was the final AT detection for a particular tag at the ENT receiver (the receiver closest to the FSC)?
   - IF Y, THEN, “Likely Detection Pattern” (LDP)
   - ELSE GOTO B
- Was the final AT detection for a particular tag at the NW, SW or MID receivers (the next-most spatially proximate receivers)?
   - IF Y, THEN “Plausible Detection Pattern” (PDP)
   - ELSE, “Unlikely Detection Pattern” (UDP)
   - GOTO C
- Was the directionality of the final AT detections toward, away, or neutral with respect to the FSC capture facility?
   - IF Toward, THEN “+”
   - IF Away, THEN “-”
   - IF Neutral, THEN “0”
   - GOTO D
- Was the time difference between PIT tag detection and the final AT tag detection greater than 1 day?
   - IF Y, THEN “Unlikely Time Difference” (UTD)
   - IF N, THEN “Likely Time Difference” (LTD)

Our algorithmic approach to determining whether we had reasonable confidence that the detection data for a given tag suggested behaviors of free-swimming juvenile salmonids reliable, or if the fish should be removed from analysis was as follows:

- IF (UDP AND (“-” OR “0”) AND UTD) THEN “Discard”
- ELSE “Keep” UNLESS UTD

As a note, this algorithm served two functions: 1) explore the tag record data, in order to conceptualize behaviors of fish and validate the QA process that was subsequently implemented, and 2) provide the basis for rigorous and repeatable elimination of tags with a low likelihood of reflecting juvenile salmonid swimming behaviors. Function 1 helped us to determine whether timestamp manipulation was warranted and could be justified, and aided efforts to generate alternative hypothesize for explaining observed patterns within the data. Moreover, function 1 enabled us to simplify this algorithm for the purposes of function 2 (*i.e.*, QA) as:

- IF UTD, THEN “Discard”
- ELSE “Keep”

# Analytical Approach

Here, we report on our overall approach to determining $P_{CE}$ and smolt use of a newly installed guide net. We also describe construction of a logistic model that we employed to develop inference regarding strength, sign, and significance of hypothesized causative factors underlying collection efficiency (*e.g.*, passage) at the FSC.

## *Collection Efficiency ($P_{CE}$)*

The collection efficiency metric, $P_{CE}$, is a component of the entire Swift Reservoir smolt survival estimate ($S_{RES}$), specified in Section 2.2 of the M&E Plan (PacifiCorp and Cowlitz PUD 2016). For the current study, $P_{CE}$ was defined as the percentage of all tagged juvenile salmonid smolts that were detected at the ZOI (*i.e.*, available for collection at the FSC), and that were subsequently detected within the FSC (*i.e.*, collected for downstream passage around Swift Dam). An individual fish was considered detected within the FSC if it was confirmed by a PIT tag detection within the FSC and was not removed by the QA-QC process outlined above in the Data management section. Additional metrics presented in this study include the following (see Table 3 for definitions):

1) Rate of detection within the study ($P_{Study}$),

2) Rate of reservoir survival ($P_{Res}$),

3) Rate of detection in the ZOI ($P_{ZOI}$),

4) Study wide capture efficiency (capture rate between tagging event to detection at the FSC, $C_{study}$),

5) FSC capture efficiency for fish that were detected within the study area ($C_{detected}$), and

6) FSC capture efficiency for fish that were detected within the forebay ($C_{forebay}$).

These metrics were calculated for all salmonid fish tagged in the study, and were subsequently calculated for each salmonid fish species that was tagged, as well as for each method of capture prior to tagging (*i.e.*, RST, FSC, or hook and line).

## What drives collection rates?

To quantify the strength and significance of the effects that multiple independent factors exerted on $P_{CE}$ over the past two (2) years (2015 – 2016) at the Swift FSC, we employed a logistic regression modeling approach. Here, it is important to explicitly recognize that although the study comprises data for two (2) years, our analysis is essentially unreplicated. This means that, for example, effects of guide net placement or similar operational differences between years are confounded with effects more strongly influenced by background environmental differences between years (*e.g.*, hydrologic or other climatologic differences). Data spanning additional years and/or locations are required to tease apart these background annual and water year effects from operational effects that can be feasibly and meaningfully manipulated.

For the construction of our model, we included a suite of variables hypothesized to influence fish behaviors that affect $P_{CE}$ and ultimately successfully passage. This set of candidate factors was determined from previous years' results, our own experience, conversations with PacifiCorp staff, and the literature, and included capture location, release year, species, release day, the first detection day at the entrance receiver, forebay residence time, and reservoir residence time (Table 1). Prior to formal model testing, all variables were tested for collinearity during the initial stages of model construction. All candidate variables were found not to be collinear (*i.e.*, all were orthogonal), with the exception of forebay residence time and reservoir residence time. This is as would be expected, because forebay residence time is essentially a subset of reservoir residence time: the two metrics differ only by the amount of time required for a smolt to swim from the release site to the study site.

Table 1. Descriptions of variables included in the logistic model.

| Variables | Definition | Type | Range |
|---|---|---|---|
| Capture Location | Where/how fish was captured prior to tagging | Categorical | • FSC (floating surface collector)<br>• Rotary Screw Trap (located at head of Swift Reservoir)<br>• H&L (Hook and Line capture) |
| Release Year | Year fish was tagged and subsequently released into study area | Categorical | • 2015<br>• 2016 |
| Fork Length | Length of tagged fish | Numerical | Continuous |
| Species | Fish species into which a tag was implanted | Categorical | • Coho (CO)<br>• Spring Chinook (CH)<br>• Steelhead (SH) |
| Release Day | Day of the year the tagged fish was released into Swift | Discrete | 1-365 (Decimal days) |

| | | | |
|---|---|---|---|
| | Reservoir | | |
| Entrance Receiver First Detection Day | Day of the year, in decimal days, that a fish was first detected at the ENT receiver | Discrete | 1-365 (Decimal days) |
| Forebay Residence Time | Calculated as the difference between first and final AT detections | Numerical | Continuous |
| Reservoir Residence Time | Calculated as the difference between release and final AT detection | Numerical | Continuous |

Logistic regression analyzes the strength of continuously and categorically measured factors in relation to a dichotomous (categorical) response variable instead of a continuous random variable (Gotelli and Ellison 2012), and is thus well suited to this dataset (*i.e.*, fish ultimately were either collected or not collected). The relationship between successful/unsuccessful capture and the various reservoir/forebay variables were therefore not linear but sigmoidal (logistic) curves that originate with a minimum value and ends at a maximum asymptote, inflecting near some estimated threshold value.

Capture of fish at the FSC was transformed using the logit transformation to convert the sigmoidal logistic probability curve function into a straight line. A maximum likelihood approach was then used for hypothesis testing, including estimation of the regression coefficients and error variance. The final logistic regression model was then constructed to maximize the likelihood of predicting capture of fish at the FSC from the most informative available predictor parameters.

Candidate predictor variables were examined for multicollinearity prior to model building, because logistic regression assumes that predictor variables are orthogonal and independent. To do this, we used a Pearson's correlation coefficient matrix to determine which variables were highly correlated, and then removed those from the initial full model. To avoid both the theoretical and the practical pitfalls associated with overparameterization (Gotelli and Ellison 2012), we used a stepwise criteria-based hybrid method that started with the full model (*i.e.*, containing all candidate factors), and subsequently removed individual predictor variables until the Akaike Information Criterion (AIC) value for a given model iteration stopped decreasing. Then, this minimum adequate (reduced) model was compared to the full model, using an Analysis of Variance (ANOVA) with a Chi-square test to test for a significant difference between the respective predictive power of the two models. Finally, the minimum adequate model was selected only if there was no statistical difference between the two; alternatively, the full model was re-evaluated, and ultimately accepted if no reduced model provided similar explanatory fit to the data. This final step in our process ensures simultaneous optimization of the competing interests of model prediction accuracy and generality, while maintaining ease of interpretation of model output.

Once a model was selected (full or reduced), model fit was further assessed using a combination of approaches. First, strength of the model was determined by using an ANOVA and subsequent Chi-square test to evaluate the hypothesis that the slope of the final model was significantly different from the null model (*i.e.*, the grand mean, with an associated slope of zero). Next, a confusion table was calculated, to determine the sensitivity and specificity of the model. This table is calculated using a subset of the original data to calculate misclassification rate.

As a note, twenty-five fish were removed from this analysis because they exhibited a forebay residence time of zero (0) days but reservoir residence times that were greater than zero (*i.e.*, >0). Potential reasons for this finding are explored below in the Discussion section.

## *How is the guide net used?*

To visualize and analyze fish movements in front of the FSC, and to infer fish movement patterns along the newly installed guide net, we applied a version of network (graph) theory (Wilson 1996). All detections zones were represented as nodes, and the movements of individual fish between detection zones were represented as directed connections (paths) between nodes. Movement patterns were then analyzed both visually and quantitatively. If fish tended to move towards or away from the FSC along the guide net, we would expect to see thick paths on the visual analysis results between the ENT, MID and EST nodes. In particular, we were interested in path interactions shown in Figure 3, which represent all directional permutations of detection histories that are possible from detections at three (3) receivers. Next, network diagrams representing the study area were created for visual analysis. The thickness and color of paths representing fish movements are weighted such that thicker, darker lines indicate a larger weight (*i.e.*, more behaviors of this pattern). It is important to note that paths are not weighted the same way in all diagrams (*i.e.*, depending on whether individual fish or individual behaviors are being visualized/analyzed). The specific weighting used in each network diagram is described and reported in the figure caption – in this circumstance the weighting was based on total number of paths (*i.e.*, not individual fish). A transition matrix was used to determine the chance that a fish detected at one receiver would next be detected at any of the other receivers.

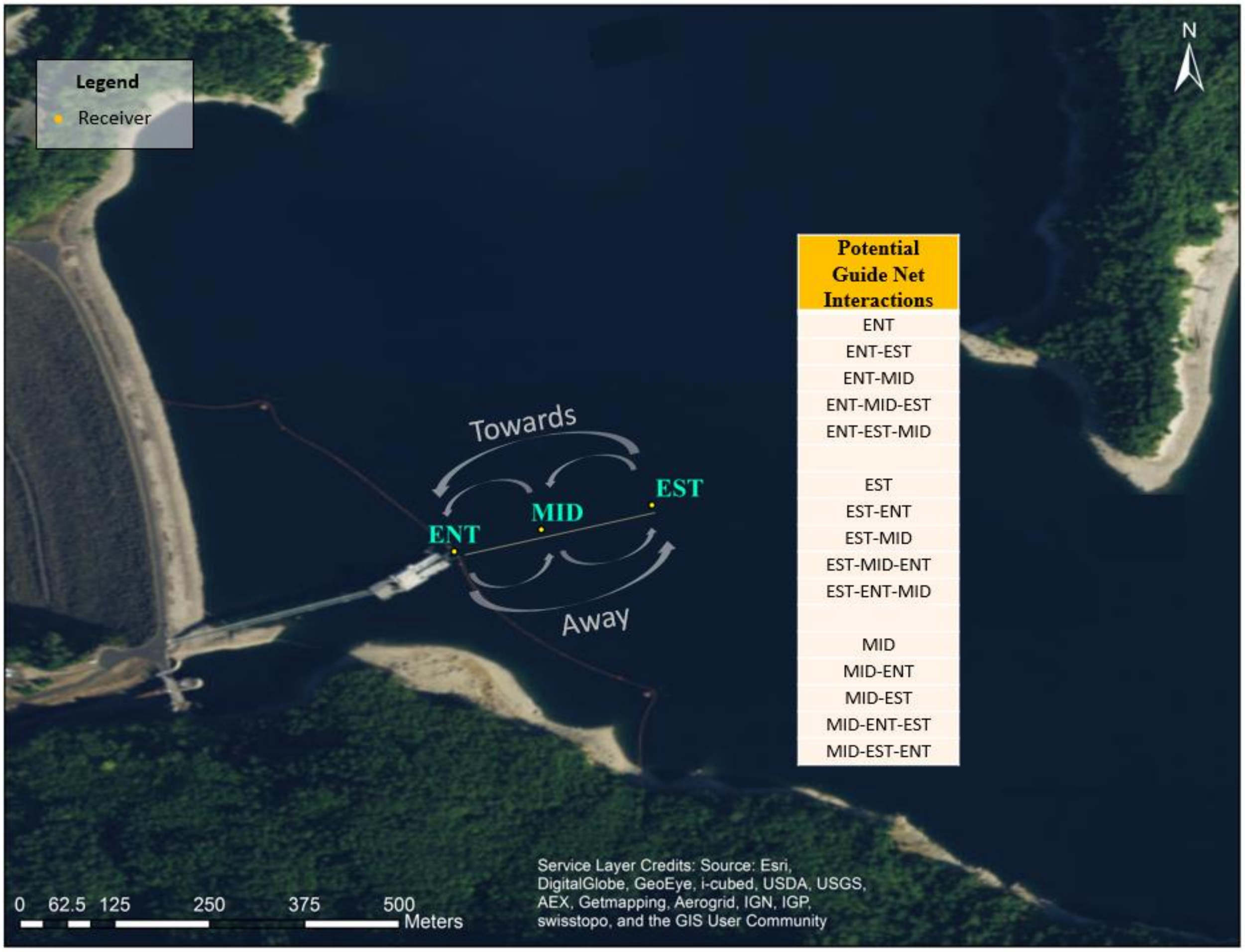



Figure 3. Diagram of select receivers deployed along the guide net, with potential fish pathway interactions along the structure that we queried for in the guide net analysis.

## *How is the timing of FSC passage related to reservoir water temperature?*

In order to better understand the influence of reservoir water temperature on juvenile salmonid passage through the Swift Reservoir study area, we plotted water temperatures in Swift Reservoir against cumulative frequency of fish collection. Our approach began with calculating running 7-day averages of the daily averaged (7DADA) hourly water temperatures that were recorded by loggers located at depths similar to those used by out-migrating salmonid smolts, *i.e.*, 0.6 – 9m below the surface (Beeman and Adams 2015; Drenner et al. 2012). These were drawn from temperature loggers deployed adjacent to the FSC at fixed elevations ASL. As the reservoir surface elevation varied, mean water depths of the temperature loggers were calculated each day (see above, Equation 1). As a note, following visual inspection of the temperature data, a single outlier temperature record (11.5°C) was removed from 4/22/2016, based on an unrealistic magnitude of temperature difference between that record and the two temporally adjacent records (immediately prior and immediately post).

# RESULTS

## Summary

A total of 205 fish were captured, surgically implanted with AT and PIT tags, and released into Swift Reservoir during 21 April – 6 June 2016 (Table 2). The AT array was removed from Swift Reservoir on 15 July 2016. Only healthy fish which were free from injury and displaying signs of smoltification were tagged. Tagged and released fish were dominated by coho (n=162) and steelhead (n=40). Less than 1% of captured fish were spring Chinook (n=3). Steelhead fork length (FL) averaged 220mm (range: 151-274mm), coho FL averaged 165mm (range: 91-271mm), and spring Chinook averaged 126mm (range: 117-135mm) (Table 2). Six (6) coho were removed from analyses based on sequences and patterns of detections that were incongruous with free-swimming juvenile smolt behaviors, as a result of the QA process we underwent (see "*Data Management, QA process*" section below). Consequently, we report on and analyze the results from 199 fish in 2016. We explored a number of lines of inquiry besides reporting on the $P_{CE}$ of the FSC:

1. What drives 2015 and 2016 collection rates ($P_{CE}$)?
2. How is the guide net used by approaching smolts; is the guide net effective at directing fish toward the FSC?
3. How is the timing of FSC passage related to reservoir water temperatures?

We also report on a number of individuals that were detected at the FSC this year that were tagged in 2015 (Reynolds et al. 2015) and we re-calculate an updated $P_{CE}$ for 2015 with the inclusion of first and second-year out-migrant life histories (see "*Delayed Migrant*" section below).

Table 2. Total number and average length of tagged fish organized by species.

| | Coho salmon | | Spring Chinook | | Steelhead | |
|---|---|---|---|---|---|---|
| **Release Date** | **Total Released** | **Mean FL (mm)** | **Total Released** | **Mean FL (mm)** | **Total Released** | **Mean FL (mm)** |
| 4/21/2016 | 7 | 121 | 1 | 117 | 2 | 182 |
| 4/29/2016 | 5 | 167 | 0 | | 0 | 0 |
| 5/3/2016 | 3 | 258 | 0 | | 1 | 241 |
| 5/4/2016 | 4 | 150 | 0 | | 0 | 0 |
| 5/9/2016 | 11 | 170 | 0 | | 4 | 217 |
| 5/11/2016 | 15 | 174 | 0 | | 5 | 222 |
| 5/12/2016 | 19 | 165 | 0 | | 5 | 219 |
| 5/17/2016 | 14 | 150 | 1 | 125 | 4 | 237 |
| 5/19/2016 | 15 | 148 | 0 | | 5 | 223 |
| 5/24/2016 | 2 | 120 | 1 | 135 | 2 | 208 |
| 5/25/2016 | 3 | 141 | 0 | | 0 | 0 |
| 6/3/2016 | 29 | 172 | 0 | | 11 | 220 |
| 6/7/2016 | 20 | 179 | 0 | | 0 | 0 |
| 6/9/2016 | 15 | 166 | 0 | | 1 | 220 |
| **Species Grand Total** | **162** | | **3** | | **40** | |
| **Species Grand Mean** | | **165** | | **126** | | **220** |
| **Species FL Range** | | **(91 - 135mm)** | | **(117 - 135mm)** | | **(151 - 274mm)** |

## Data Management: QA Process

Two key findings emerged from our data management QA-QA procedure:

1. PIT and AT receivers exhibit time stamp discrepancies, resulting in seemingly illogical spatial sequences of detections.
2. A non-trivial number of fish express delayed migration, resulting in no acoustic detections on the year they are tagged, and only a PIT tag detection the following year.

Using the first QA algorithm (AT detections immediately pre and post PIT detection), we determined that, of 23 tag codes with problematic detection histories, 19 exhibited AT→PIT→AT patterns that are unlikely to reflect true behaviors of free-swimming juvenile salmonids. Four (4) tags exhibited AT→PIT→AT patterns that were plausible, zero (0) of which exhibited a final detection at the ENT acoustic receiver. Taken together, these findings suggest a time stamp discrepancy between the AT and PIT receivers. Consequently, we relatively adjusted PIT tag detection time stamps on those records not subsequently determined to warrant discard (using our second algorithm), so that the PIT tag detection at the FSC occurred ten seconds after the final AT detection.

From our second QA algorithm, we determined that 17 of the 23 fish with problematic temporal sequences of AT→PIT→AT exhibited PIT and AT time stamp discrepancies of 44 – 149 minutes, and 13 of these 17 exhibited highly consistent discrepancies of 52 minutes. The other six (6) tag codes exhibited larger discrepancies, approaching 7 weeks. We determined that these six (6) tag codes warranted removal from analyses, due to an unlikely combination of records including substantial durations (3.5 – 47.8 days) of AT detections after a particular fish ostensibly was “captured” at the FSC (*i.e.*, as determined by PIT tag receiver records). In order to assess the magnitude of effect size associated with inclusion/removal of these six fish, analyses were run with and without including them; all core regulatory metrics changed by $\pm \leq 2\%$ (data not shown). Of note, an additional four (4) tag codes exhibited combinations of unlikely or possible detection histories ((UDP OR PDP) AND outward or neutral directionality displayed on their final acoustic detections (“-” OR “0”) AND likely time differences between the acoustic and PIT tag timestamps (LTD)), which we interpreted as *insufficient* evidence to warrant discarding. However, these patterns contain useful information, and raise the following two possibilities:

1. This tag record does not reflect behaviors of a free-swimming juvenile salmonid, or
2. The AT array is characterized by holes in detection capacity, which may or may not be addressable by changing layout, orientation, or equipment in future years.

Moreover, two (2) tag codes exhibited combinations of ((LDP OR PDP) AND (“+” OR “0”) AND (UTD)). These two (2) tags were detected within the AT array for 26.1 – 47.8 days following the PIT tag detection at the FSC. We interpreted these patterns as highly unlikely to reflect actual behavior of free-swimming juvenile salmonids, and more likely to reflect the outcome of some alternative, which we hypothesize to be predation (*e.g.*, by hatchery rainbow trout which have been observed in the area of the FSC and are frequently captured at the FSC). This inference of predation was further supported by the following circumstantial evidence:

- Reports of approximately 55,000 hatchery rainbow trout (*Oncorhynchus mykiss*) being released into Swift Reservoir during 2015 for the purposes of supplementing a recreational trout fishery (Chris Karchesky, PacifiCorp, personal communication)
- Anecdotal accounts of observations of fish swimming near the FSC (Mark Ferraiolo, PacifiCorp, personal communication), and
- Receiver detection histories for these tags suggesting substantial time spent milling upstream of the FSC.

Based on these observations, we simplified our initial algorithm for the purposes of QA to (IF UTD, THEN "Discard"). However, it bears mentioning that this simplified version may not be appropriate in future scenarios. We recommend retaining our full QA algorithm going forward, in order to identify unlikely combinations of detections that suggest non-free-swimming juvenile salmonid behaviors.

## Tag failure, tag loss, decay rate, post-release mortality

All PIT tag records from the FSC were analyzed and compared to AT receiver data recorded in the forebay and ZOI. Two (2) fish (1% of 199 fish) were tagged in 2016 and subsequently captured at the FSC, but were never detected within the AT array, suggesting tag or battery failure or acoustic tag loss combined with PIT tag retention.

Of the 199 fish that were released at the head of the reservoir, 174 (87%) entered the forebay area, approximately 15 km (9.3 mi) downstream from their release site, and 25 fish did not enter the forebay. Three manual tracking events were complete on June 8, June 22, and July 4, 2016. Of the 25 that did not enter the forebay, 2 were detected via mobile tracking efforts in the upstream half of the reservoir, and the remaining 23were never recorded. During mobile tracking events none of the detected tags were located in the same spot over multiple surveying dates, indicating that post-release mortality is likely trivial.

The general movement patterns observed during the acoustic manual tracking data were similar to those made previously during the Swift Reservoir smolt behavior studies prior to the construction of the FSC (PacifiCorp 2001; PacifiCorp 2002). Fish appeared to migrate easily to the forebay area and after they did not successfully pass, moved widely throughout the reservoir. Numerous fish transitioned the length of the reservoir multiple times. In general tagged fish seemed to congregate in the forebay and at the head of the reservoir; those that were not congregated appeared to be spread evenly about the reservoir and near the shorelines. Figures of the mobile tracking events are shown in Appendix B.

## Collection Efficiency ($P_{CE}$)

205 fish were tagged in 2016 (*T*, Table 3), and mean FL (averaged per tagging event) across all species was 117 – 258 mm (4.6 – 10.2 in) FL (Table 3). Out of the 199 fish that were tagged in 2016 and included in subsequent analysis (*N*, Table 3), 170 fish (85% of *N*) were captured for tagging at the FSC, and thus were non-naïve upon re-entry to the AT array study site. An additional 25 fish (13% of *N*) were captured for tagging at the Eagle Cliff ST, upstream of the reservoir, and 4 fish (2% of *N*) were captured for tagging via hook-and-line sampling at spatially distributed locations throughout the reservoir.

Table 3. Summary of passage metrics for tagged fish organized by species and release location. Six coho were removed from the study after tagging (see QA section of report for details).

| | | *Coho Salmon* | | | | *Spring Chinook Salmon* | | | | *Steelhead* | | | | ***Grand Total*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metric Description** | **Notation** | **ST** | **H&L** | **FSC** | **Total** | **ST** | **H&L** | **FSC** | **Total** | **ST** | **H&L** | **FSC** | **Total** | |
| Total Tagged | *T* | 20 | 4 | 138 | **162** | 2 | 0 | 1 | **3** | 5 | 0 | 35 | 40 | **205** |
| Total Included in Study | *N* | 18 | 4 | 134 | **156** | 2 | 0 | 1 | **3** | 5 | 0 | 35 | 40 | **199** |
| All detections in the study area | *A* | 16 | 4 | 124 | **144** | 1 | 0 | 0 | **1** | 4 | 0 | 28 | 32 | **177** |
| Detected at Shoreline (North OR South) | *S* | 11 | 4 | 113 | **128** | 1 | 0 | 0 | **1** | 4 | 0 | 18 | 22 | **151** |
| Detected at Shoreline but ***not*** Forebay | *S~R* | 0 | 0 | 3 | **3** | 0 | 0 | 0 | **0** | 0 | 0 | 3 | 3 | **6** |
| Detected in Forebay (*i.e., all non-shoreline receivers*) | *R* | 15 | 4 | 121 | **140** | 1 | 0 | 0 | **1** | 4 | 0 | 24 | 28 | **169** |
| Detected in Forebay but ***not*** Shoreline | *R~S* | 5 | 0 | 11 | **16** | 0 | 0 | 0 | **0** | 0 | 0 | 10 | 10 | **26** |
| Detected @ ZOI (ENT detections) | *D* | 11 | 3 | 84 | **98** | 1 | 0 | 0 | **1** | 4 | 0 | 13 | 17 | **116** |
| Captured @ FSC | *C* | 3 | 4 | 23 | **30** | 0 | 0 | 0 | **0** | 0 | 0 | 4 | 4 | **34** |
| Rate of detection within the study ($P_{Study}$) | *A/N* | 89% | 100% | 93% | **92%** | 50% | N/A | 0% | **33%** | 80% | N/A | 80% | 80% | **89%** |
| Rate of reservoir survival (i.e., rate of detection within the forebay) ($P_{RES}$) | *R/N* | 83% | 100% | 90% | **90%** | 50% | N/A | 0% | **33%** | 80% | N/A | 69% | 70% | **85%** |
| Rate of detection in the ZOI ($P_{ZOI}$) | *D/N* | 61% | 75% | 63% | **63%** | 50% | N/A | 0% | **33%** | 80% | N/A | 37% | 43% | **58%** |
| Study-wide (Tagging to FSC) capture efficiency ($C_{study}$) | *C/N* | 17% | 100% | 17% | **19%** | 0% | N/A | 0% | **0%** | 0% | N/A | 11% | 10% | **17%** |
| FSC capture efficiency for fish that were detected within study ($C_{detected}$) | *C/A* | 19% | 100% | 19% | **21%** | 0% | N/A | N/A | **0%** | 0% | N/A | 14% | 13% | **19%** |
| FSC capture efficiency for fish that were detected within the forebay ($C_{forebay}$) | *C/R* | 20% | 100% | 19% | **21%** | 0% | N/A | N/A | **0%** | 0% | N/A | 17% | 14% | **20%** |
| **FSC capture efficiency for fish detected within the ZOI (Operational Collection Efficiency) ($P_{CE}$)** | ***C/D*** | 27% | 133% | 27% | **31%** | 0% | N/A | N/A | **0%** | 0% | N/A | 31% | **24%** | **29%** |

Of these 199 fish included in analyses (*N*, Table 3), 177 fish (88% of *N*) were detected by ≥ one (1) receiver within the AT array (*A*, Table 3), 169 fish (84% of *N*) were detected in the forebay (*R*, Table 3) and 34 fish (17% of *N*) were ultimately captured (in some cases, re-captured) at the FSC (*C*, Table 3, Figure 4). Among all fish included in the study 58% were detected in the ZOI ($P_{ZOI}$) (Table 3). Only six (6) fish were detected on the north or south shore but not in the forebay (*S~R*, Table 3). 26 fish were detected in the forebay but not detected on the south or north shore receivers (*R~S*, Table 3). Among all fish included in the study, 29% of fish that were detected in the ZOI were subsequently captured by the FSC ($P_{CE}$, Table 3 and see shaded area of Figure 4). When considering $P_{CE}$ by species, coho exhibited the greatest $P_{CE}$ at 31%; zero Chinook were captured at the FSC giving Chinook a $P_{CE}$ of 0%; steelhead exhibited an intermediate $P_{CE}$ of 29%. When considering all fish included in the study (*N*), study-wide capture efficiency ($C_{detected}$, Table 3) was 19%, indicating that a modest number of tagged fish were never detected in the vicinity of the FSC. Interestingly, 100% of the four (4) coho that were initially captured for tagging using hook-and-line were captured at the FSC, and only three (3, i.e., 75%) of these were detected at the ZOI prior to capture at the FSC, leading to $P_{CE}$ > 100% for this group (Table 3). However, the small sample size associated with this group constrains the scope of inference possible from these data, rendering this observation of anomalously high $P_{CE}$ for hook-and-line coho essentially anecdotal.

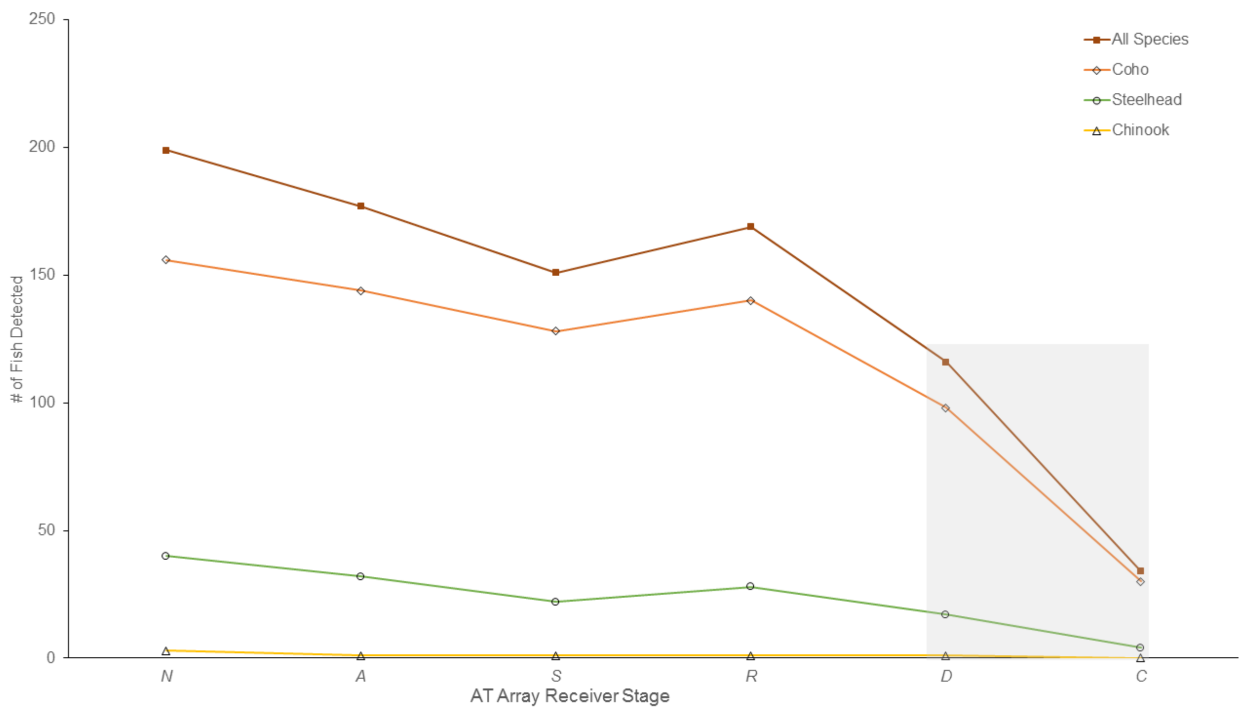



Figure 4. Number of detections at successive stages within the Swift Reservoir AT array, for all species (closed squares connected by red-brown line), coho (open diamonds connected by orange line), steelhead (open circles connected by green line), and Chinook (open triangles connected by dark yellow line). X axis is a linearized depiction of procession through the AT array within Swift Reservoir. Notations for stage within the array of AT recievers are as follows: *N* = number of tagged fish included in analyses after QA, *A* = number of fish detected within the study area, *S* = Number of fish detected at either the North or South shoreline, *R* = number of fish detected in the forebay, *D* = number of fish detected at the ZOI, and

*C* = number of fish captured at the FSC, as determined by a PIT tag detection within the FSC. Gray shaded area highlights the detections used for determining passage efficiency ($P_{CE}$).

## What drives collection rates?

Summary statistics for the continuous variables used for the model are listed in Appendix Table 1. Our reduced and full models did not statistically differ in predictive capacity, and the two models' $R^2$ values were nearly identical ($R^2$ = 0.10 and 0.07, respectively for full and reduced model). A VIF table and correlation matrix (Appendix Table 2 and Appendix Table 3) suggested that there is multicollinearity present in the reduced model, deriving from collinearity between Forebay Residence Time and Reservoir Residence Time. As a result, we removed Forebay Residence Time from the final model, in order to focus on the potentially more meaningful, and easily interpretable Reservoir Residence Time. Architecture of the final reduced model indicates that the primary contributing factors underlying successful passage at the FSC include: Capture Location, Species, Release Day, Reservoir Residence Time, and Fork Length.

*Capture Location* – In 2015 and 2016 three different capture methods/sites were employed. Of these, hook and line capture resulted in the highest recapture rate (26%), which was approximately 10 percentage points higher (*i.e.*, a 73% difference) compared to either FSC- or screw trap-captured fish (Table 4).

*Species* – Across both years (*i.e.*, 2015 and 2016), 17 Chinook, 239 coho and 73 steelhead were included in this analysis. Of all these tagged fish, 0% of Chinook, 18% of coho and 16% of steelhead were recaptured at the FSC (Tbale 4).

- *Release Day* - The average and median release date for recaptured fish was slightly earlier than for non-recaptured fish. Also, fifty percent of all recaptured fish occurred across a 16 day window. For non-recaptured fish this range was 6 days longer (Figure 5). The temporal distribution of release day showing the frequency of recaptured and non-recaptured fish can be found in Appendix Figure 1.

- *Reservoir Residence Time* – The average and median number of days spent in the reservoir were lower for recaptured fish than for non-recaptured fish. Similarly, the interquartile range of reservoir residence time (*i.e.*, duration between first and last detection among AT receivers within the reservoir) for recaptured fish was approximately 29 days, as compared to approximately 35 days for fish that were not recaptured at the FSC (Figure 6). It should be noted that a substantial portion of non-recaptured fish would be expected to remain in the reservoir, meaning that this difference is likely even greater. The temporal distribution of reservoir residence time showing the frequency of recaptured and non-recaptured fish can be found in Appendix Figure 2.

- *Fork length* – Smolts were tagged across a broad range of sizes, from 91 – 274mm fork length (FL, Figure 7). Recaptured fish followed a similar pattern to non-recaptured fish, but the densest cluster of recaptures measured between 115 – 130mm FL. The temporal distribution of fork length showing the frequency of recaptured and non-recapatured fish can be found in Appendix Figure 3.

Table 4. Total number and percent of recaptured and non-recaptured individuals by capture location and species.

| Metric | No-recap | Recap |
|---|---|---|
| *Capture Location* | | |
| FSC | 144 (84%) | 26 (15%) |
| H&L | 25 (73%) | 9 (26%) |
| Screw Trap | 126 (63%) | 33 (16%) |
| *Species* | | |
| CK | 17 (100%) | (0%) |
| CO | 239 (81%) | 55 (18%) |
| SH | 73 (83%) | 14 (16%) |

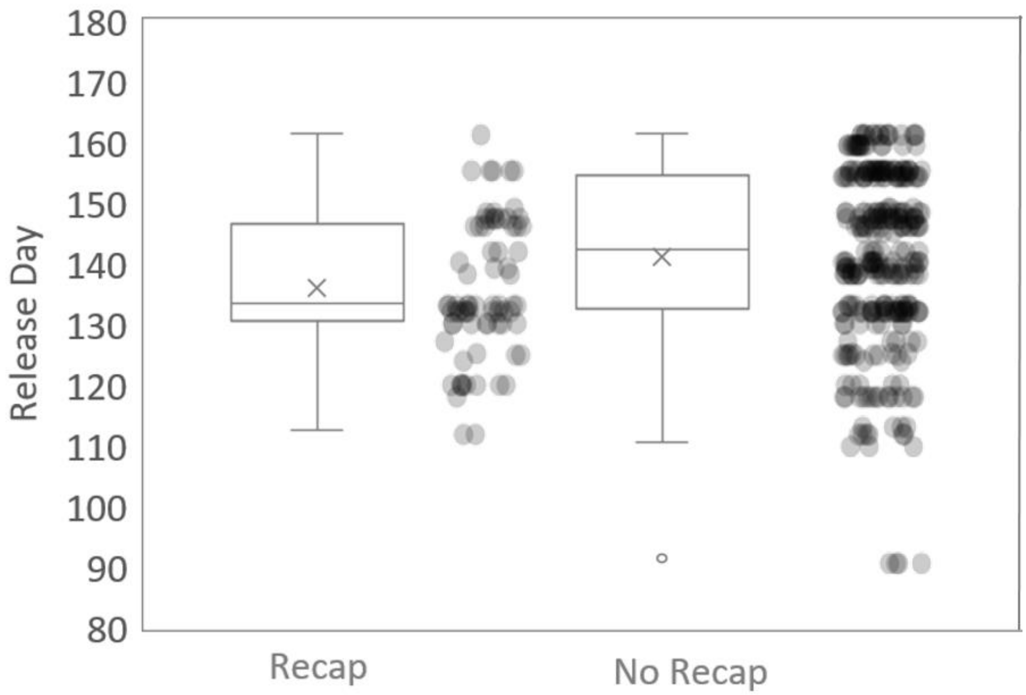



Figure 5. Box and whisker plot and scatterplot of fork length for recaptured versus non-recaptured fish. X indicates average value. Outliers on box and whiskers are indicated with an open o.

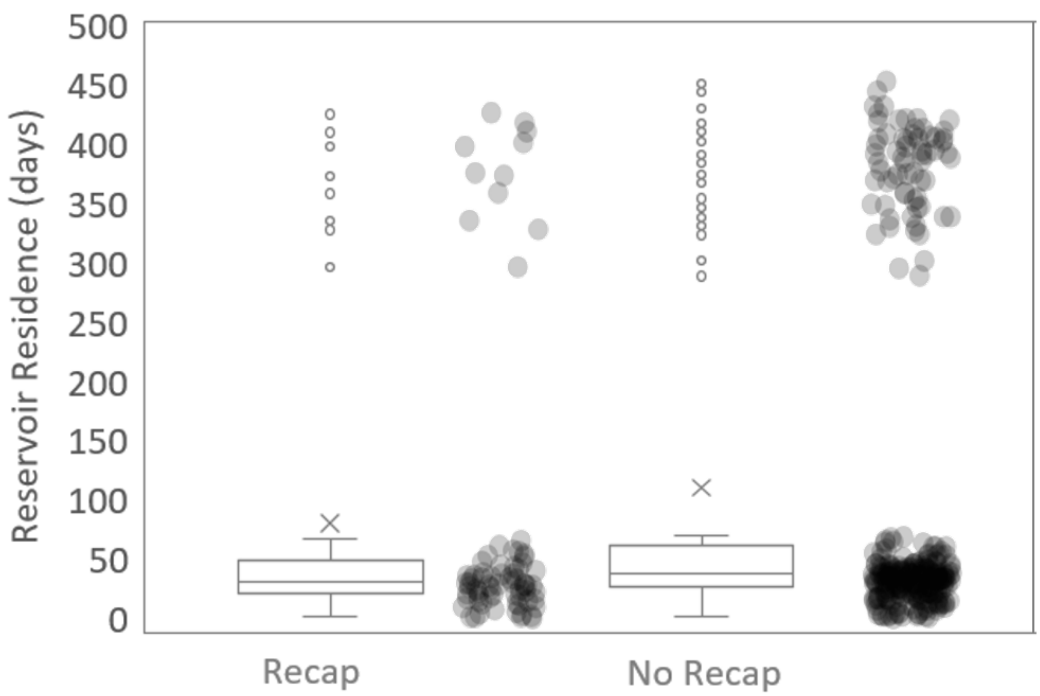



Figure 6. Box and whisker plot and scatterplot of the reservoir residence time for recaptured and non-recaptured fish. X indicates average value. Outliers on box and whiskers are indicated with an open o.

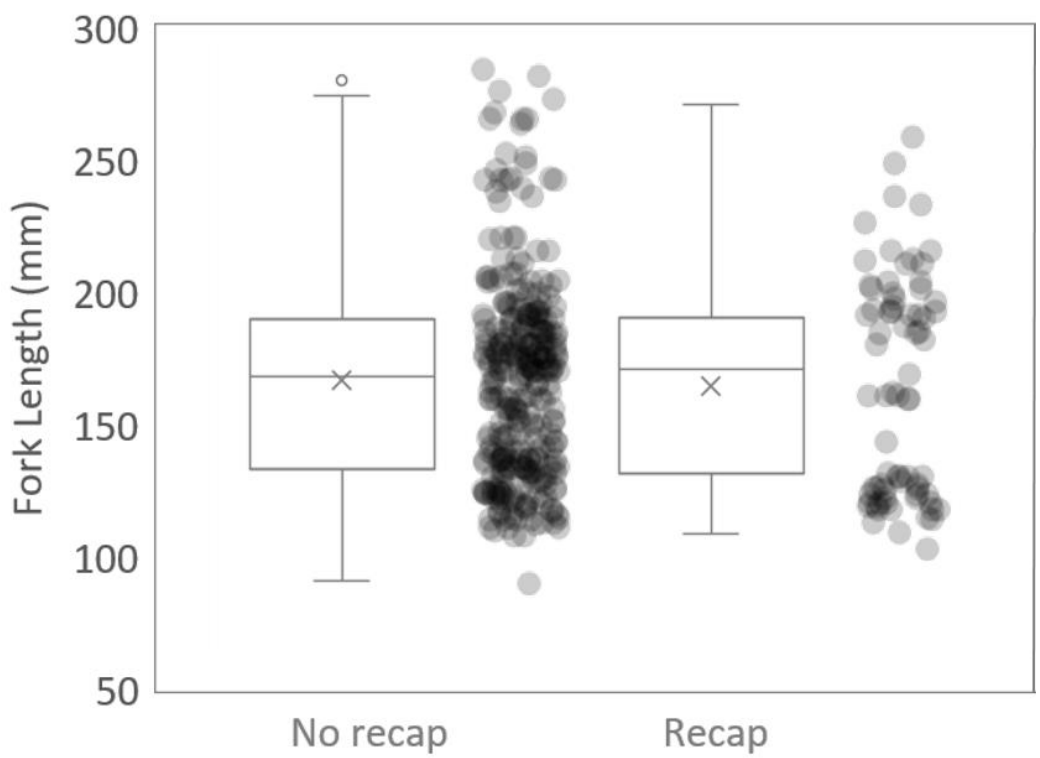
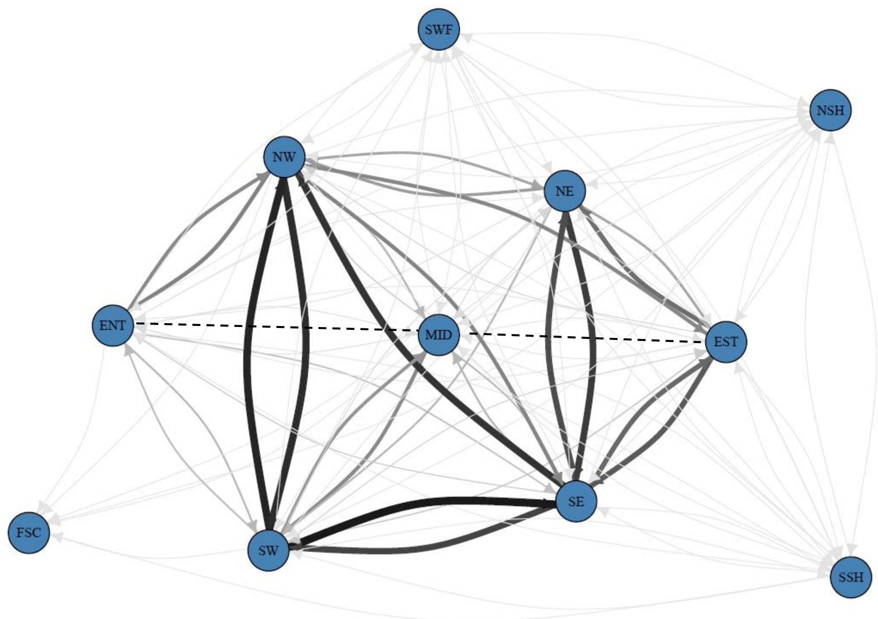



Figure 7. Box and whisker plot and scatterplot of the fork length for recaptured and non-recaptured fish. X indicates average value. Outliers on box and whiskers are indicated with an open o.

The two variables that had the most substantial effect on collection rates were capture location and species. The remaining continuous variables included in our final model each had relatively modest effect sizes. Taken together the model correctly predicted capture outcome (*i.e.*, recapture or no recapture) 85% of the time and misclassified 15%. Notably, our model very accurately identifies individuals that were *not* recaptured (approximately 98% accurate), but only moderately accurately predicts individuals that were recaptured (approximately 30% of the time). Thus, the model can be considered more specific than sensitive. Consequently, below we develop discussions and recommendations that focus on factors that may prevent fish from successfully negotiating Swift Reservoir for collection at the FSC.

## How is the guide net used?

A visual analysis of the network diagram for fish movements throughout the study area illustrates the tendency of fish to move widely along the front of the FSC, but not to enter the ZOI or the FSC itself. No clear travel path emerges for moving through the forebay toward the FSC in the network diagram (Figure 8). The most heavily utilized paths (*i.e.*., the heaviest and darkest lines) lead to a cyclic behavior between: 1) NW↔SW; 2) SE↔SW; or 3) NW→SE. The most heavily used pathway that leads to ENT originated from NW. Notably strong paths do not connect MID to ENT, which we would suspect if the guide net had helped orient smolts toward the FSC. Instead, tracking data indicate that fish may be sounding under the net (*i.e.*, as indicated by subsequent detections at NW, NE, or SWF receivers).




[2]

Figure 8. Network diagram of movement within the study area at Swift Reservoir, 2016. Path thickness is scaled based on the total number of transitions that occurred across all tagged individuals. Site abbreviations are listed in Figure 1. Black dashed line connecting ENT, MID, and EST receivers indicates the location of the guide net.

The individual transition probabilities graph (Figure 9) illustrates the set of probabilities describing where a fish would next move based on current position. From examining this matrix, it becomes apparent that there is no consistently traveled path for fish moving through the forebay into the FSC along the guide net. Of particular interest are the EST and MID receivers that are placed along the guide net. When an individual fish had just been detected at EST, there was a 44% probability that it would next be detected at SE, and a 38% probability that it would be detected at NE. The remaining 18% of fish transitioned from EST to ENT, MID, NW, and SW. When an individual fish had just been detected at MID—located directly in front of the ENT receiver—there was a 47% probability that it would next be detected at SW, and 23% probability that it would next be detected at SE. The remaining 30% of fish transitioned from MID to ENT, EST, NE and NW.

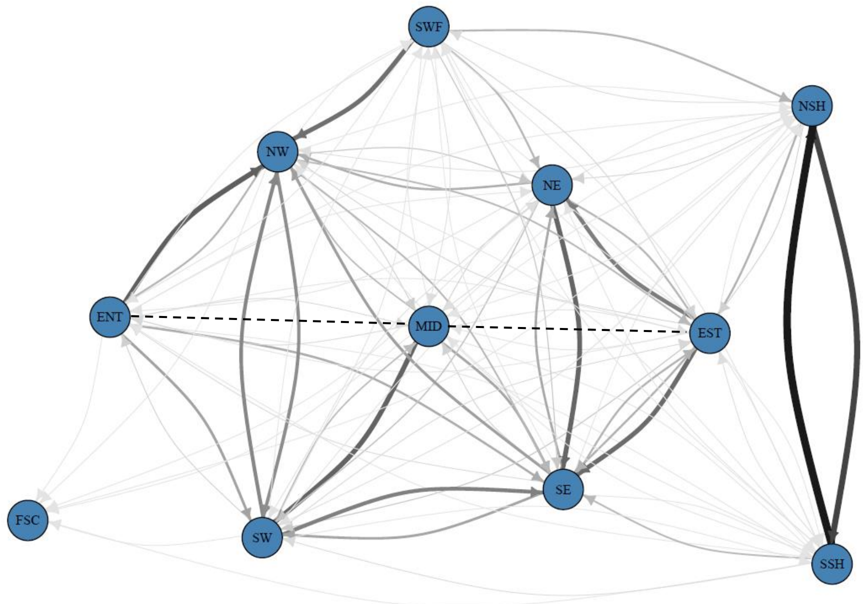
Regarding accessing the ZOI, fish appeared to approach predominantly from Swift Creek Arm: Fish that had just been detected at SWF exhibited a 43% probability of being detected next at NW, and once at NW, fish then exhibited a 17% probability of being detected next at ENT. Together, this SWF→NW→ENT pathway was the most probable pathway that led to in a fish getting to the ZOI. This suggest that fish are not extensively using the guide net, and appear to approach from Swift Creek Arm and the north side of the FSC.

[2] This graphic shows the total number of transitions that occurred across all 199 smolts throughout the study, 178 of which were detected at some point by the AT array. Spatial scale and receiver orientation to one another are not accurate. Dashed line connecting ENT, MID, and EST receivers indicates the location of the guide net.

Importantly, fish that had just been detected at ENT (*i.e.*, fish within the ZOI) exhibited an approximately 49% probability of being detected next at NW, a 20% probability of being detected next at SW, and a 24% probability of being detected next at SW. The small remainder of fish (<5%) transitioned to MID, NE, or EST. Notably, there was an approximately 0.01% probability that a fish that had just been detected at ENT would be detected next within the FSC.

Generally, fish that were located at forebay receivers (*e.g.*, within the double-diamond formation) tended to remain within the diamond rather than moving either toward the FSC or away from the FSC, toward the shoreline receivers. In other words, the most common next transition for fish located in the forebay was adjacent or across from where they were currently located.

Fish that had just been located along the NSH or SSH had the highest likelihood of transitioning to the opposing shoreline. Fish at SSH had a 75% likelihood of moving north to NSH and fish from NSH had a 59% chance of moving south to SSH. Also of note, there were numerous transitions from the various forebay receivers towards either NSH or SSH (light grey paths that end at the shoreline receivers).




[3]

Figure 9. Network diagram of movement within the study area at Swift Reservoir, 2016. Path thickness is scaled based probability of selecting that path from the current node (transition probabilities). Site abbreviations are the same as they are listed in Figure 1. FSC = fish detected with PIT tags at the FSC; ENT = entrance to FSC (*e.g.*, the ZOI); NW, SN, NE, SE = receivers directly in front of the FSC; MID and EST = receivers along the guide net; NSH and SSH = receivers placed on north and south shorelines upstream of the forebay; SWF = receiver north of the FSC in a bay. Black dashed line connecting ENT, MID, and EST receivers indicates the location of the guide net.

Holding or milling most likely occurred at the sites with the most visits, including: SE, SW and NW (Figure 8, Figure 10). The sites that had the most number of transitions that led back to themselves, which are more likely involved in holding behavior, include: NSH, SSH (Figure 11). Of note, this figure suggests that 1) fish have more self-transitions at NW and SW than NE or SW, and 2) fish have fewer self-transitions at MID and EST than any of the other double-diamond receivers.

[3] This graphic shows the percent likelihood of a fish moving from a given node to all other nodes (*e.g.*, For all non-terminal sites the sum of all outgoing arrows sums to 1). The only terminal site is the FSC in this circumstance. Spatial scale and receiver orientation to one another are not accurate.

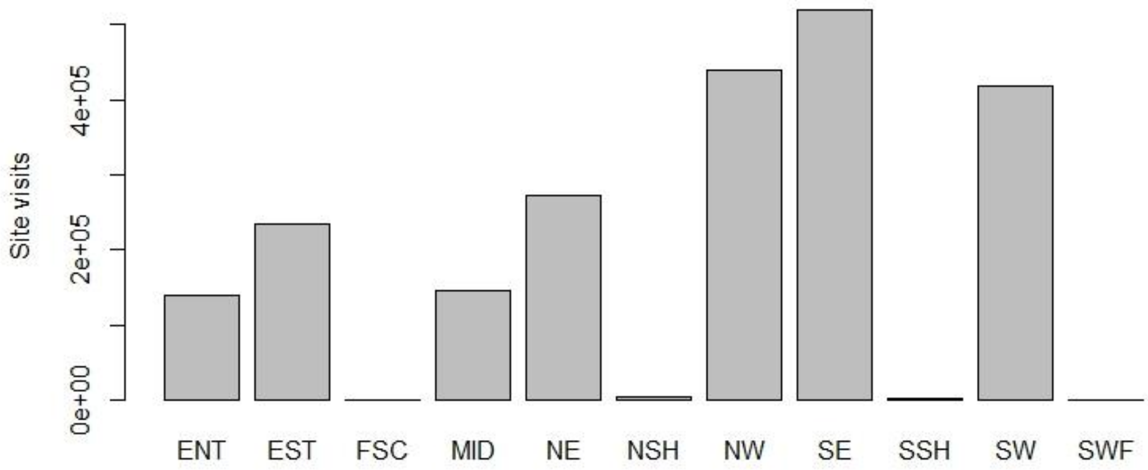



Figure 10. Total number of site visits at each receiver. Sites with a high number of visits are sites likely involved in milling.

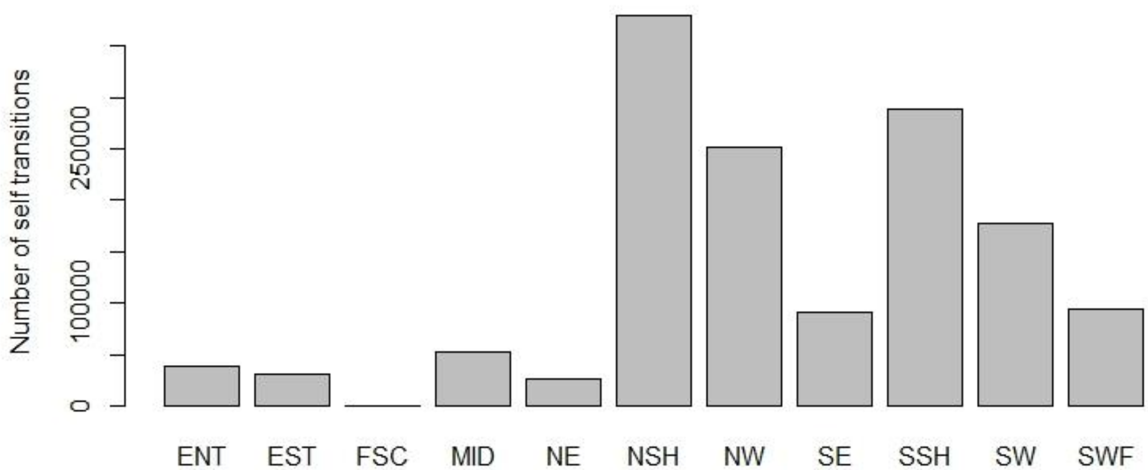



Figure 11. Total number of site visits with repeated site visits at the same location (*i.e.*, can be thought of as holding behavior; a proxy for residence time).

## How is the timing of FSC passage related to reservoir water temperature?

In 2016 80% of collected smolts had been collected before the 7DADA reached 15°C and 99% of all passed before 7DADA exceeded 16°C (Figure 12).

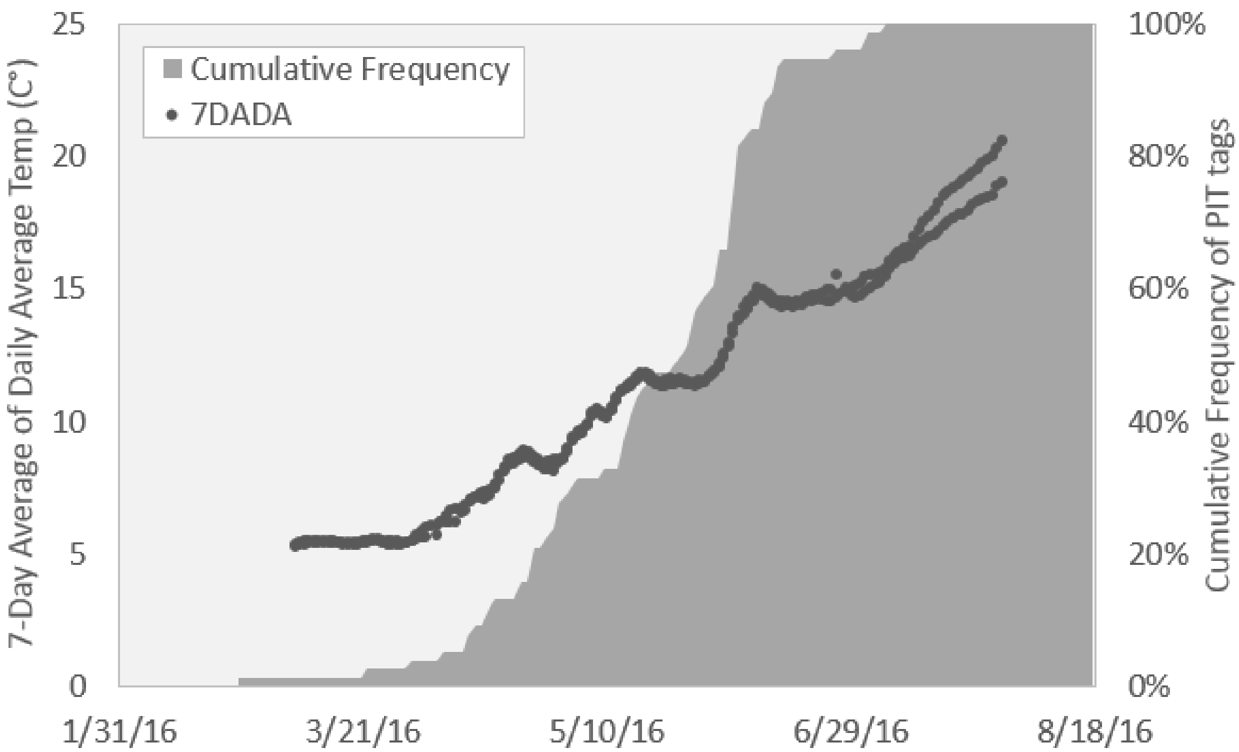



Figure 12. Cumulative frequency of PIT tags collected at the FSC during spring – summer 2016 (shaded area to the right of the gray line) plotted alongside the 7DADA water temperature in Swift Reservoir (0.3 – 10m depth below surface).

## Delayed migration

One unexpected finding of the QA process this year was the contribution of a considerable number of 2015 tagged fish that appear to have out-migrated in 2016: 16 coho and three (3) steelhead appear to have expressed delayed migration. Overall, 9.5% (19 of 200) of the tagged fish from 2015 appear to have delayed migration by a full year. Unfortunately, the batteries powering the acoustic transmitters in these fish were no longer active, and thus we cannot know if/how these fish interacted with the guide net nor the ZOI.

In 2015, 13 coho were captured at the FSC, out of 110 coho that were detected within the ZOI, for a $P_{CE}$ of 12%. If these, 16 coho that appear to have delayed migration until 2016 are included in the $P_{CE}$ calculation for 2015 outmigrant coho, by adding 16 to both the number captured (numerator) and the number detected at the ZOI (denominator), then the new $P_{CE}$ for 2015 coho outmigrants would be 29/126 = 23%.

Similarly, in 2015 there were 8 steelhead collected at the FSC and 43 detected at the ZOI. Adding 3 additional fish to these values increases the $P_{CE}$ for 2015 steelhead from 19% to 24%.

The overall reported $P_{CE}$ across all species in 2015 was 21/159 (13%). If all fish that appear to have delayed migration and out-migrated during 2016 are included in this calculation, then this number would be updated to 40/178 (23%).

# DISCUSSION

This year, CFS focused on three main areas of inquiry: 1) determining collection rates ($P_{CE}$); 2) exploring factors hypothesized to underlie successful passage through Swift Reservoir; and 3) inferring fish interactions with the recently installed guide net, in order to assess guide net efficacy. In addition to these core products, we report a non-trivial number of juvenile salmonids – primarily coho – that appear to have delayed migration. Finally, we discuss a number of the anomalous detection patterns highlighted during our QA process, including potential implications.

## Collection Rates

$P_{CE}$ is an estimate of collection efficiency that is calculated by dividing the total number of fish which are collected at the FSC (*C*, Table 3) by the number of fish that were present in the ZOI at any time in their AT array detection history (*D*, Table 3), based on the explicit assumption that a detection at the ZOI indicates that an individual fish was "available" for FSC capture (*i.e.*, passage). In 2013, reported collection efficiency ($P_{CE}$) was 6% (Courter et al. 2013), in 2014 $P_{CE}$ was 27% (Stroud et al. 2014), in 2015 $P_{CE}$ was 13% (Reynolds et al. 2015), and in the current year (2016), $P_{CE}$ was 28%. We advise appropriate caution in interpreting apparent trends within this set, as technologies, tag type, and release methodologies have changed over the years. Reynolds et al. (2015) suggest that the detection zone associated with the more recent tag technologies may be larger, which could in part explain the apparent reduction in $P_{CE}$ between 2014 and 2015. Moreover, based on the 19 fish from the 2015 cohort of out-migrating juvenile salmonids for which PIT tag detections at the FSC during 2016 suggest delayed out-migration, we anticipate more fish from the 2016 cohort to move downstream next year, as 19 (9.5% of 200) individuals that were tagged in 2015 appear to have expressed delayed migration and were detected at the FSC in 2016.

## Factors Underlying Successful Passage

The results of our logistic modeling effort indicate that collection rates differ among species, and that collection rates may be driven in part by fork length at tagging, location of capture prior to tagging, release day after tagging, and duration that individual fish spend residing in Swift Reservoir. Notably, almost all smolts were collected at the FSC before reservoir temperatures reached 16 °C, an observation that is aligned with previous findings that juvenile coho occupancy declines markedly when T > 16 °C (Welsh et al. 2001), and with current USEPA guidelines regarding maximum salmon core juvenile rearing temperatures (USEPA 2003). In future work scopes and resolution of inference regarding causative factors underlying successful passage could both be improved by including additional data, such as swimming depth that individual fish experience. From our findings, below we develop operational and logistic recommendations for increasing passage success rates in future years.

## Guide Net Efficacy

Previous iterations of the juvenile fish passage study undertaken by CFS for PacifiCorp have investigated the pathways by which fish first approach the forebay area, and found that a considerable number of smolts were first detected on the north shoreline before redirecting to the south shoreline for their final approach to the FSC. The installation of a guide net on the face of the FSC was intended to increase the number of fish that swim straight into the attractive velocities at the collector, rather than swimming in a rounded clockwise path along the Swift "gyre" (Black and Veatch 2007) from the Northshore (NSH) to the South Shore (SSH) receivers.

The guide net interaction detection pattern network analysis suggested that the guide net receivers were not heavily used in 2016, although it is impossible to discern whether this was a result of 1) MID and EST not detecting some fish when they were using the guide net (given that telemetry detections are <100% with any telemetry study); or 2) the fish not utilizing the area along the guide net. This year (2016), the most heavily used nodes include SW, SE, NE, and NW, suggesting that fish spent considerable time transiting between these zones. The most frequent pathway that led to an ENT detection was SWF→NW→ENT.

We suspect that the MID and EST receivers recorded considerably fewer detections than the other double diamond receivers, possibly the result of mooring these receivers > 300% deeper than receivers at SW, SE, NE, or NW (which itself was a measure taken to *improve* detection probability). There are several pieces of evidence which support this hypothesis: 1) fish had fewer self-transitions at MID and EST than any of the other double-diamond receivers; and 2) fish had fewer overall detections at MID and EST but the signal strength and receiver capabilities for the AT technology were designed to have mostly overlapping spheres (and thus, very similar numbers of hits). For these reasons, we are not inclined to reject the hypothesis that the guide net was ineffective, and instead contend that another year of data are needed with receivers at comparable depths in order to make inference about guide net usage.

Finally, movement patterns inferred during the current (2016) study contradict some of the findings reported in 2015. In 2015, 34% of fish approached the FSC from the NSH, and another 23% of fish were first detected at NSH but then moved clockwise down to SSH before heading towards the FSC. Cyclic movements between SSH and NSH remain prevalent this year, but there actually appear to have been *more* SSH to NSH than NSH to SSH movements in 2016 – the opposite direction than was identified in 2015.

## Anomalies detected during QA

Problematic detection sequences arose when AT array detections occurred after detection within the FSC of the PIT tag associated with that fish. PIT tag detection inside the FSC ostensibly *should* signify removal of an individual fish from the study area, in preparation for transport around Swift Dam and ultimately downstream passage. Thus, acoustic detections after the PIT detection suggest at least three possible underlying scenarios:

1) The clock responsible for generating the time stamp associated with the PIT tag detection in the FSC either
   a. substantially differed from the weekly-calibrated clocks within the AT receivers comprised within the study area array, or
   b. experienced time drift across the study season.
2) The out-migrating smolt associated with tags generating an anomalous detection history was preyed upon, the predatory individual (*e.g.*, a hatchery origin reservoir resident *Oncorhynchus mykiss*) was captured at the FSC, and this individual was then re-released into the Swift Reservoir, as previously reported (Mark Ferraiolo, PacifiCorp, personal communication).

   The out-migrating smolt associated with tags generating an anomalous detection history shed the acoustic tag either before or during capture at the FSC, and the expunged acoustic tag settled into tank debris at the FSC before inadvertently being sent back into the reservoir with the other tank debris.

## Recommendations

In future years, timestamp uncertainty associated with the FSC PIT tag detector should be addressed, *e.g.*, by implementing daily or weekly logged PIT tag clock calibration, or by installing a networked PIT tag detector that automatically calibrates itself to a standardized (*e.g.*, GPS) clock at regular intervals.

In addition, we recommend that PacifiCorp implement consistent protocol for cases when fish other than those associated with the ongoing out-migration study (*i.e.*, non-juvenile salmonid smolts such as resident trout) are encountered at the FSC. In particular, valuable information could be gained (and predation of study species may potentially be reduced) by adopting the following when resident trout are encountered:

- Scanning the fish for both
  - PIT tag, and
  - AT tag.
- If fish scan positive for a tag, then:
  - Recording the observation in a daily log book or electronic worksheet, including the following data:
    - Species,
    - Approximate size,
    - Date,
    - Time, and
    - Observer.
  - Removing the fish from the immediate vicinity of the FSC, *e.g.*, below Swift dam or to a location upstream.

We also recommend visual inspection of debris removed from the FSC for obvious tags, and suggest relocating debris to a designated site, out of range of the AT array.

More resolute and informative behavioral data could be collected by implanting transmitting pressure sensors with the acoustic in order to collect individually-experienced data for both successfully and unsuccessfully passed fish.

Other recommendations stemming from factors potentially affecting passage that were highlighted by the logistic model include the following:

> 1) *Capture Location*: Exert more capture effort with hook and line sampling and Eagle Cliff RST rather than the FSC. Fish collected at the FSC have the lowest likelihood to be recaptured at the FSC. They are also non-naïve to the study site, suggesting a negative behavioral capture bias may occur with these individuals.
>
> 2) *Release Date*: Exert more tagging / releasing effort in an earlier and tighter time window prior to May 26.

To quantify the number of fish moving away from the reservoir rather than emigrating downstream following release (*e.g.*, and perhaps displayed delayed migration), future evaluations could involve setting up additional receivers above and below Eagle Cliff.

Additionally, emerging technologies associated with unmanned water vehicles (*i.e.*, boat drones), such as mounted side scan sonar, could be systematically deployed in a targeted manner during peak out-migration times, in order to develop more resolute behavioral inference regarding the manner in which out-migrating smolts interact with the guide net.

We recommend setting up a 1-day experiment next year with the EST and MID receivers in order to determine the optimized deployment depth to capture out-migrating smolts.

Finally, in order to better quantify predation, which our data suggest may modestly reduce the likelihood that tagged fish enter the reservoir ($P_{RES}$), all or a subset of tagged fish could be implanted with predation fuses. Data resulting from deployment of this technology could enable evaluation of 1) predation rates, and 2) differences in movement patterns between smolts and their predators.

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# APPENDIX A: LOGISTIC MODEL

Appendix Table 1. Summary statistics for continuous predictor variables in the final reduced model.

| Variable | n | Mean | SD | Median | Min | Max | 25th | 75th |
|---|---|---|---|---|---|---|---|---|
| Fork length | 338 | 165 | 38 | 169 | 13 | 282 | 132 | 190 |
| Release Day | 338 | 140 | 14 | 141 | 91 | 161 | 133 | 149 |
| Reservoir Residence | 338 | 110 | 147 | 37 | 1 | 451 | 26 | 61 |

Appendix Table 2. Correlation matrix for continuous variables in the reduced model. *Forebay residence was removed in the final reduced model.

| | FL | Release Day | ENT First Detect Day | Reservoir Residence | Forebay Residence* |
|---|---|---|---|---|---|
| FL | 1 | 0.086048 | -0.12301 | -0.14305 | -0.12895 |
| Release Day | 0.086048 | 1 | 0.020198 | -0.13047 | -0.11455 |
| ENT First Detect Day | -0.12301 | 0.020198 | 1 | 0.200118 | 0.223718 |
| Reservoir Residence | -0.14305 | -0.13047 | 0.200118 | 1 | 0.991555 |
| Forebay Residence* | -0.12895 | -0.11455 | 0.223718 | 0.991555 | 1 |

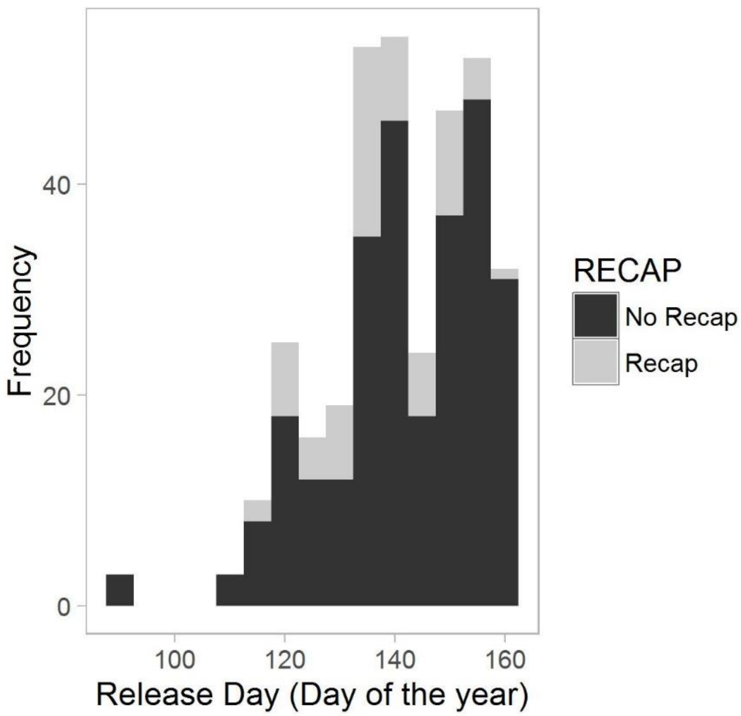
Appendix Table 3. VIF table to evaluate multicollinearity in the reduced model. *Forebay Residence was removed in the final reduced model.

| Variable | GVIF |
|---|---|
| Capture Location | 2.558271 |
| Fork length | 2.484245 |
| Species | 2.100258 |
| Release Day | 1.398711 |
| Reservoir Residence | 617.8878 |
| Forebay Residence* | 610.3315 |

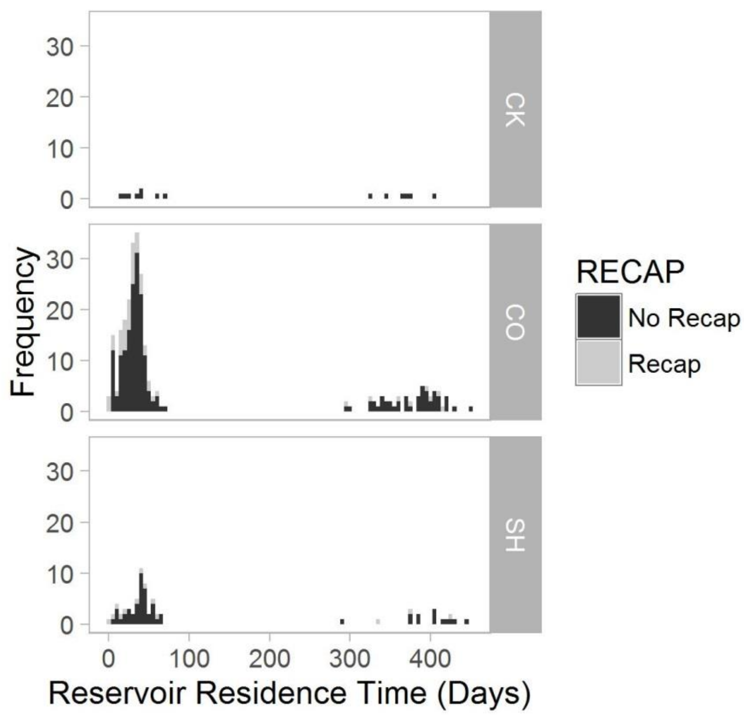
Appendix Table 4. Analysis of Variance with a Chi-square test to determine predictor significance included in the reduced model ($p<0.05$).

| Variable | df | Deviance | Residuals df | Residuals Deviance | p-value |
|---|---|---|---|---|---|
| Null | | | 337 | 336.6 | |
| Capture Location | 2 | 2.2 | 335 | 334.4 | 0.33 |
| Fork Length | 1 | 0.8 | 334 | 333.6 | 0.38 |
| Species | 2 | 8.8 | 332 | 324.8 | 0.01* |
| Release Day | 1 | 8.3 | 331 | 316.5 | <0.01* |
| Reservoir Residence | 1 | 5.1 | 330 | 311.5 | 0.02* |

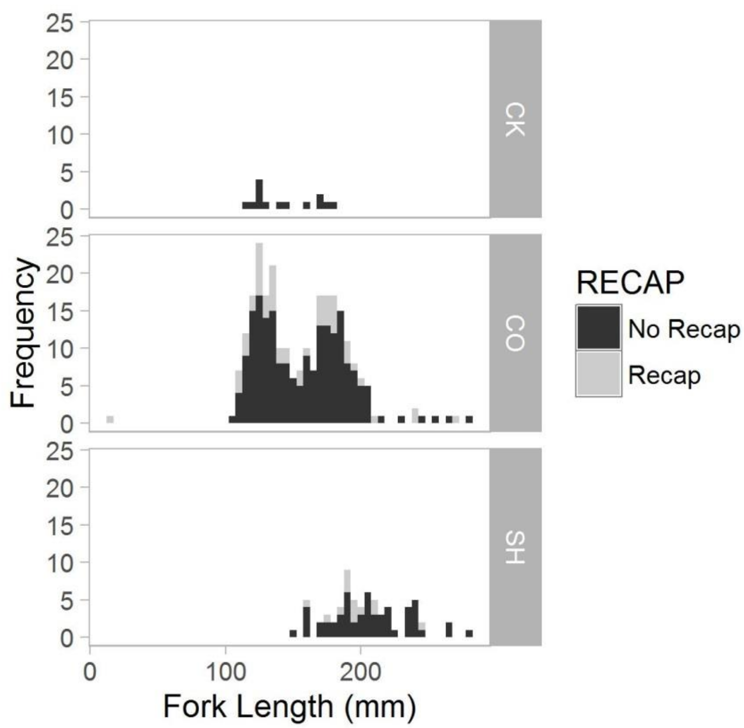
* < 0.05




Appendix Figure 1. Temporal distribution of numbers of fish tagged and released per day, with bars shaded by recap or no-recap.



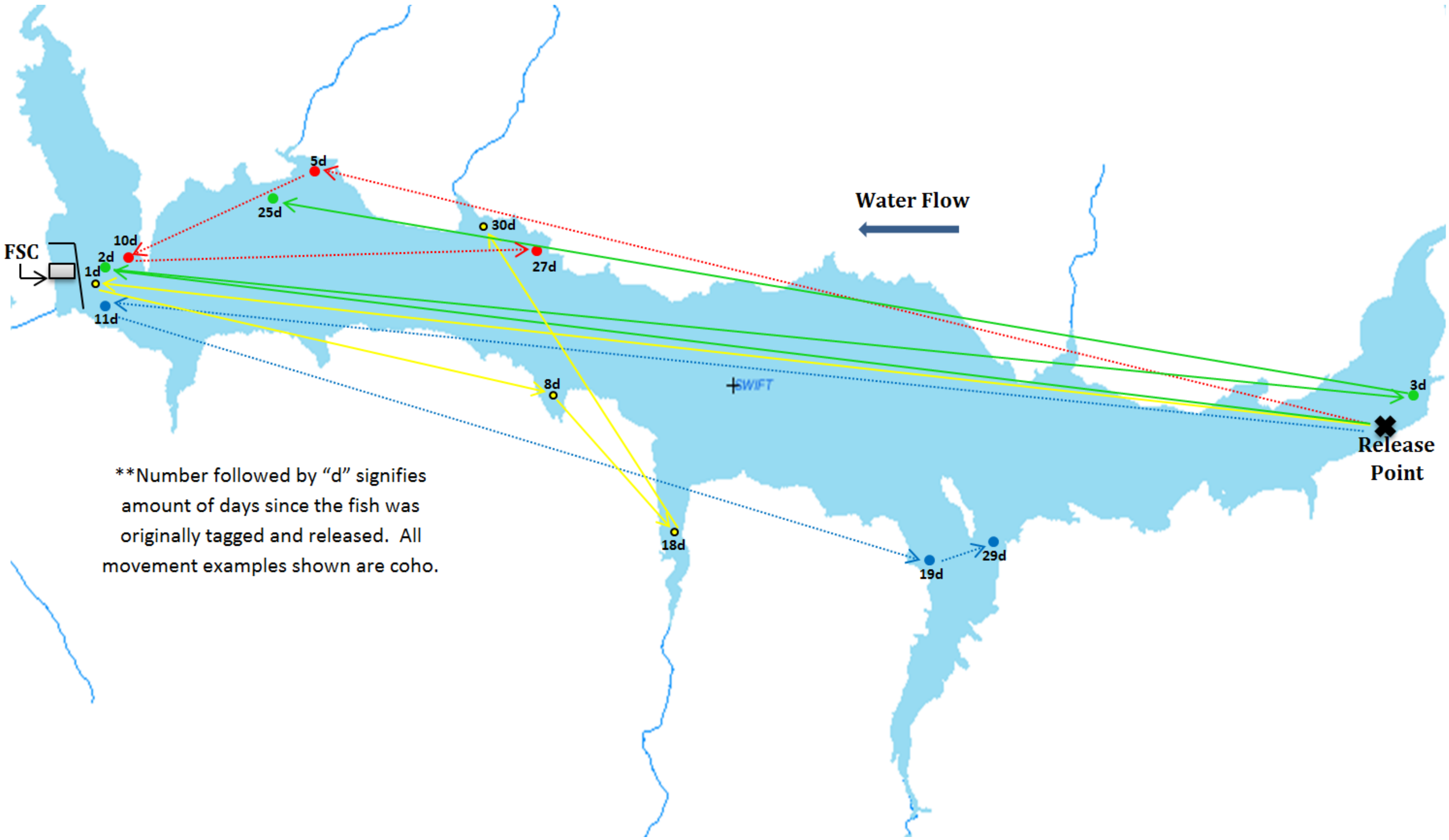

Appendix Figure 2. Distribution of reservoir residence times for tagged fish by species, with bars colored by recap or no-recap.




Appendix Figure 3. Distribution of date of fork length for tagged fish by species, with bars colored by recap or no-recap.

# APPENDIX B: MANUAL TRACKING


Appendix Figure 4. Spatial distribution results of manual tracking by date. Each dot during the associated date represents a unique fish. Uniqueness is not represented between survey dates.




Appendix Figure 4. Representative movements of four tagged coho smolts detected during multiple mobile tracking events in Spring 2016.

## APPENDIX C

## MERWIN ADULT TRAP EFFICIENCY EVALUATION – 2016 REPORT

# MERWIN UPSTREAM PASSAGE ADULT TRAP EFFICIENCY

## 2016 Final Report

*Prepared for:*

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**February 22, 2017**

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# EXECUTIVE SUMMARY


This report describes results from the second year of a radio telemetry (RT) study designed to address the requirements of the Lewis River Aquatic Monitoring and Evaluation Plan (M&E Plan; PacifiCorp and Cowlitz PUD 2016). The M&E Plan describes the need for an evaluation of the collection efficiency of the Merwin Dam adult fish trap for upstream migrating steelhead (*Oncorhynchus mykiss*), spring Chinook (*O. tshawytscha*), and coho (*O. kisutch*) salmon. Merwin Dam is the lower most hydroelectric project on the North Fork of the Lewis River and located in southwest Washington. During 2016, low return numbers of spring Chinook and coho salmon prevented their inclusion in the current study. Consequently, results presented here focus only on winter steelhead.

The M&E Plan defines a goal of 98% collection efficiency, or Adult Trap Efficiency (*ATE)* for salmonids that are available for collection below Merwin Dam and provides a framework for quantifying a core metric to estimate overall *ATE* (*i.e.*, $ATE_{test}$). *ATE* was defined as the proportion of fish entering the Merwin Dam Tailrace (*M*) that were ultimately captured (*C*). An additional metric—trap entrance efficiency ($P_{EE}$)—quantifies the proportion of fish entering the Merwin Dam Tailrace that entered the trap (*T*); including fish that entered but were not ultimately captured. A large relative difference between $P_{EE}$ and $ATE_{test}$ (*i.e.*, $\frac{P_{EE}-ATE_{test}}{P_{EE}}$, which simplifies to $\frac{T-C}{T}$) would thus reveal ineffective trapping and suggest an operational or infrastructural weak link in upstream passage at the trapping device—a failure to simply capture once they have entered the trap rather than a failure to attract fish to the trap entrance. As a point of reference, in 2015 $ATE_{test}$ and $P_{EE}$ for steelhead were 61% and 85%, respectively; $ATE_{test}$ and $P_{EE}$ for spring Chinook were 38% and 90%, respectively; and $ATE_{test}$ and $P_{EE}$ for coho were 9% and 23%, respectively (Stevens et al. 2015). (It is important to note however that the sample sizes for both spring Chinook (n=40), and coho salmon (n=35) were small compared to winter steelhead (n=148) during the 2015 study, and therefore representative inference on these species is still lacking).

The objectives of the 2016 Merwin *ATE* evaluation were to:

1) Determine $ATE_{test}$ for 2016 and compare this value to the performance standard of 98%.
2) Evaluate directional movement of fish at the trap entrance.
3) Determine if fish in the tailrace spend most of their time near the entrance of the trap or elsewhere.
4) Evaluate the amount of time fish spend in the tailrace and compare to performance standards.
5) Describe the movement and behavior of fish that do not enter the trap, and move back downstream.
6) Evaluate fish condition (*i.e.*, descaling and injury rates).
7) Evaluate key operational or structural changes that could increase *ATE*, and estimate the relative benefits of each option.

In response to findings described in Stevens et al. (2015), changes to operations, infrastructure, and other attributes influencing study design were implemented during 2016. The biggest difference in 2016 was that an ARIS 1800 acoustic camera camera was installed at the hopper of the trap to evaluate behaviors of fish that turn around in the trap. Additionally, in 2016 CFS developed four (4) *ATE* simulations to evaluate potential improvements in *ATE* that could be gained under differing operational/infrastructural scenarios.

Key results from the 2016 study pertaining to the core passage metrics include the following: 148 winter steelhead were tagged after being captured at the Merwin Dam Adult Fish Collection Facility (*i.e.*, they had been trapped once) between February 24th and May 20th, 2016. Of these, 144 were detected within the study area detection array, 128 were detected in the tailrace of Merwin Dam (composing the group of fish that were included in estimates of core metrics), 119 were detected at the trap entrance, and 94 were successfully recaptured — for an overall $P_{EE}$ of 93% and $ATE_{test}$ of 73%, respectively. These estimates were 8% and 18% higher (representing 7 percentage points and 11 percentage points, respectively) than $P_{EE}$ and $ATE_{test}$ estimated for winter steelhead in 2015 — in which $P_{EE}$ was calculated to be 86% and $ATE_{test}$ of 61%. While these changes were apparent, bias corrected and accelerated bootstrapped 95% confidence intervals (BCA 95% CI) for $P_{EE}$ and $ATE_{test}$ indicate that values for 2015 and 2016 were not significantly different.

Four of the 144 tagged fish were never detected in the study array, which would indicate failed tags, shed tags, post-release mortality, or fish swimming away from the study area after release. There was a significant effect of release date on trapping efficiency (ANOVA, $r^2 = 0.32$, $p = 0.003$) with a greater proportion of fish being recaptured when captured, tagged, and released earlier in the season. Bootstrapping and randomization was used to evaluate the observed $ATE_{test}$ values, and $ATE_{test}$ was found to be significantly less than the $ATE_{target}$ of 98%. Although $P_{EE}$ was closer to the $ATE_{target}$, the randomization simulation revealed that $P_{EE}$ was also significantly less than the $ATE_{target}$ of 98% ($p$=0.00113), indicating that, even if all fish that entered had been captured, the target would not have been met. We also compared the amount of time that fish were present in the tailrace and compared them to *ATE* performance standards; 10% of steelhead ($n$ = 14) exhibited tailrace times >168 h.

**Table 1.** 2016 values for $ATE_{test}$, $P_{EE}$, and $T_i$.

| Species | *N* | $ATE_{test}$ *(BCA 95% CI)* | $P_{EE}$ *(BCA 95% CI)* | $T_i$ |
|---|---|---|---|---|
| Winter steelhead | 144 | 73% (65-80%) | 93% (87-96%) | 21% |
| Spring Chinook | *N/A* | *N/A* | *N/A* | *N/A* |
| Coho salmon | *N/A* | *N/A* | *N/A* | *N/A* |

In addition, out of the 94 tagged fish that were recaptured only 17 (18%) were successfully recaptured during their first trap entrance, meaning they did not leave the trap once they had first "nosed in". The remaining 77 fish that were successfully recaptured (82%) exited the trap and returned to the tailrace at least once before re-entering the trap and were captured.

A key finding of the 2016 network analysis was that fish do not follow clear pathways in the tailrace. Other key findings include the following:

1) Fish most commonly first approach the North Shore rather than the South Shore.
2) Most fish which are trapped come from the South Shore.
3) The most frequent milling locations are in the tailrace (North Power Station Wall) rather than the trap or the downstream sites.
4) Most milling within the trap occurs between Hopper and Pool 1-4.

A heat map table was used to evaluate the most likely next site of detection after a fish visits each receiver. Key findings confirm the 2015 results, and also suggest that fish located within the trap do not follow clear directional paths. More than half of the fish that were eventually trapped moved between various receiver sites 100 or more times prior to being trapped, and there were no clear differences in transition rates between groups of successfully and unsuccessfully passed fish. That is, there do not appear to be distinct swimming paths associated with fish that successfully find the trap and are captured, and those that do not.. Also, fish appear to spend the majority of their time holding at the North Shore and milling at Approach receivers.

More than one quarter (*n* = 33; 26%) of the 128 radio tagged winter steelhead that returned to the tailrace after being tagged were detected at sites located downstream of Merwin Dam after being initially detected in the tailrace. That is, these 33 fish migrated upstream, were captured, tagged, and released downstream, returned upstream to the tailrace, and then volitionally moved back downstream. Of these 33 fish, 17 (approximately 50%) ultimately returned upstream (*i.e.*, a third time) and were successfully captured. The remaining 16 fish in this group were not captured, and their ultimate fate is unknown, but could include spawning in downstream tributaries or mortality.

Additionally, 95 fish (74% of the 128 fish detected in the tailrace) moved into the trap and then returned to the tailrace without being trapped during their first trap entrance. Seventy (70) of these 95 fish (74%) eventually re-entered the trap and were successfully captured. The remaining 25 fish (26%) that had entered the trap at least once were never captured.

We developed four (4) simulations to determine recommendations for future operational or infrastructural scenarios to possibly improve trap efficiency, which included: a model validation control scenario, a model simulating the installation of a new trap on the north shoreline, a model simulating changes in crowder operations, and a model simulating implementation of a deterrence system along the north shore to encourage more fish toward the trap on their first approaches. The simulation with the most promise was increasing the frequency of operation of the hopper/crowder and/or modifying the fish ladder to retain fish once they had entered the trap.

Finally, we cross-compared radio telemetry data and fish behavior images from the ARIS sonar camera that was installed in the fish crowder chamber, in order to semi-quantitatively describe the swimming direction of fish at the crowder. This analysis suggests increased frequency of crowder operations are generally associated with an increase in successful trapping of winter steelhead. Also, increased frequency of crowder operation appeared to have no detrimental impact on fish behaviors or capture efficiency.

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# INTRODUCTION

## Study Area

The Lewis River is a major tributary of the Columbia River, approximately 129 river km (RKM) upstream from the Pacific Ocean. The North Fork Lewis River hydroelectric project begins at Merwin Dam and Powerhouse at RKM 31 and extends through two (2) other impoundments. This study is focused on the approximately 20 km stretch between the Merwin Dam and the Lewis River Bed & Breakfast in Woodland, Washington, the location of the lowermost detection site (**Figure 1**). Our analyses for quantifying estimates of core passage metrics focus on those fish that were detected within the Merwin Dam tailrace, defined as the area upstream of the access bridge across the North Fork Lewis River approximately 0.1 km downstream of Merwin Dam.

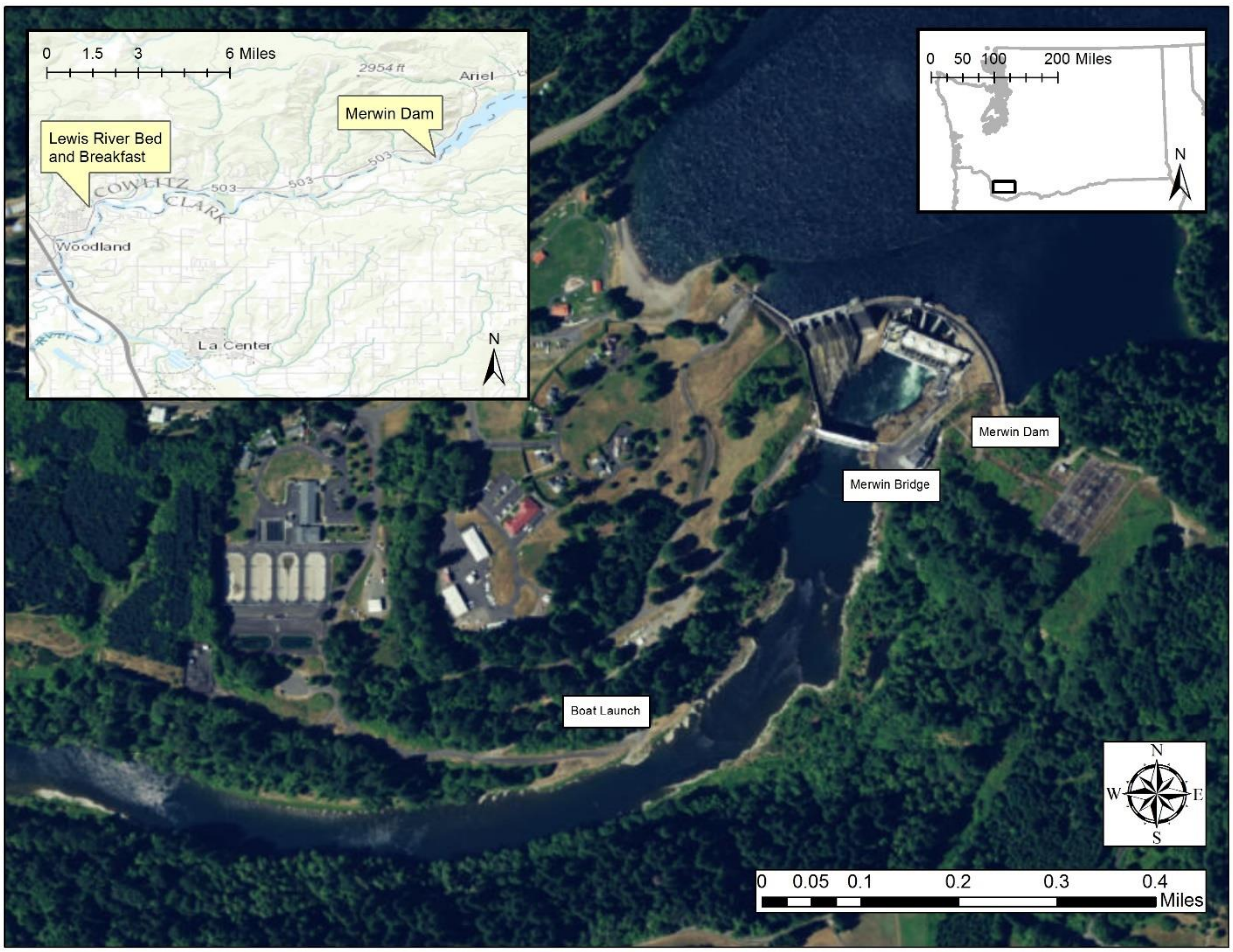


**Figure 1**. Project area map, indicating location of Merwin Dam, Bridge, and Boat Launch (large map), in addition to extent of study area within the Lewis River system (top left), and the project location within the region (top right).

# Study Background

This report describes the second year (2016) of a radio telemetry study designed to evaluate adult trap efficiency (*ATE*) of upstream migrating salmonids, and provide insight on the behaviors of fish as they approach the tailrace and trap at Merwin Dam. Phase I of the Licensing Agreement requires the reintroduction of anadromous salmonids and provision of upstream adult passage of Merwin Dam and downstream juvenile passage of Swift No.1 Dam. The primary goal of reintroduction is to achieve genetically viable, self-sustaining, naturally reproducing, and harvestable populations of spring Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and winter steelhead (*Oncorhynchus mykiss*). This goal is achievable if individual fish can complete each stage of their life cycle.

This report focuses on the immigration behavior of adult salmonids (of each target species) as they transition through the tailrace of Merwin Dam and into the adult collection facility ladder and fish crowder/conveyance system. Our evaluation centers around three core metrics of fish trapping effectiveness, $ATE_{test}$, $P_{EE}$, and $T_i$[3], which quantify the effectiveness of trapping fish that enter the tailrace, attracting fish to the trap, and the relative difference between these two, respectively.

The 2015 $ATE_{test}$, $P_{EE}$, and $T_i$ values for salmonids included in the study are given in Table 2 (modified, from Stevens et al. 2015). Bootstrapped bias-corrected and accelerated 95% confidence interval (BCA 95% CI) provided for winter steelhead metrics, to aid comparison with 2016 results.

**Table 2.** 2015 species-specific values for $ATE_{test}$, $P_{EE}$, and $T_i$.

| **Species** | ***N*** | ***$ATE_{test}$* (BCA 95% CI)** | ***$P_{EE}$* (BCA 95% CI)** | ***$T_i$*** |
|---|---|---|---|---|
| Winter steelhead | 146 | 61% (51-67%) | 86% (79-90%) | 29% |
| Spring Chinook | 40 | 38% | 90% | 58% |
| Coho Salmon | 35 | 9% | 23% | 61% |

As evidenced by the relatively high $T_i$ values in 2015 (particularly for spring Chinook and coho), fish included in the study showed higher rates of locating and entering the trap compared to being successfully trapped. Stevens et al. (2015) inferred that fish are probably locating the attraction flow and entering the trap, but that some factor related to the transition between Pool 1-4 and the hopper impedes forward progress into the trap and preventing capture.

[3] See *Analytical Approach* section, page 13, for a description of how passage metrics are calculated.

## Study Objectives

This study was designed to address the requirements of the Lewis River Aquatic Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2016), which describes the need to evaluate the effectiveness of the Merwin Dam Adult Fish Collection Facility.

This year, an array of 18 radio telemetry antennas and receivers (monitoring stations) were positioned strategically to evaluate fish movements downstream, at the tailrace, and within section of the adult collection facility. The objectives for the 2016 evaluation period included the following:

1) Determine *ATE* as defined in the M&E plan for each target species, and compare those estimates to the performance standard of 98% and to the trap attractiveness metric $P_{EE}$.
2) Determine if fish show direct movement to the trap entrance and, if some fish do not, document the behavior patterns for those specific fish in the tailrace.
3) Determine if fish in the tailrace spend the majority of their time in the area of the entrance of the trap and, if some fish do not, determine if those fish are holding or milling in another location within the tailrace.
4) Determine the median and total time fish are present in Merwin Dam tailrace and compare to *ATE* performance standards for safe, timely, and effective passage.
5) Describe the movement and behavior of tagged fish that do not enter or which choose to leave the Merwin Dam tailrace and move back downstream.
6) Determine the condition of fish that are captured by the trap, as a function of rates of descaling and injury.
7) Evaluate the operational variables which impact fish behaviors toward or away from the trap through the operation of four (4) model simulations including: a control, the installation of a new trap on the north shoreline, changes in crowder operations, and a deterrence system along the north shore to encourage more fish toward the trap on their first approaches.
8) Cross-evaluate fish behaviors using both RT and an ARIS sonar camera to anecdotally and semi-quantitatively describe the swimming direction of fish at the crowder.

# METHODS

## Fish Collecting and Tagging

PacifiCorp staff were responsible for the fish collecting and tagging efforts. Late-run winter steelhead were tagged from late-February through late-May, 2016. To maximize the probability that these fish were volitionally targeting upstream spawning habitat, fish were captured at the Merwin Dam Adult Fish Collection Facility. Consequently, all fish included in the study had previously navigated and were successfully captured by the trap. One explicit assumption of this study and subsequent analyses is thus that recapture rates of non-naïve fish accurately and appropriately reflect, and effectively equal, rates of initial capture among naïve fish.

A maximum limit of 25 fish were tagged and released on any given day, with a total target of 150 individuals per study species. To provide adequate temporal coverage of the run and capture underlying variability in passage rates within the run, captures were temporally protracted over nearly three months. Two types of tags were used in this study. The first was a Lotek MCFT-3A coded transmitter tag (166.660 MHz)d, that measured 16 mm in diameter and 46 mm in length, and had a mass of 16 g, giving it a weight of 157 millinewtons in air but only 66 millinewtons in water. MCFT-3A tags were programmed with a burst rate of 5 s, staggered by 0.5 s intervals within release groups (4.5 s; 5 s; and 5.5 s delays). This, combined with reducing the number of fish in each release group, reduced the frequency of tag collision. The second style tag was a MCFT-3A-LAT1400 coded transmitter tag (166.660 MHz) and an archival depth logger. These tags measured 16 mm in diameter and 88 mm in length, and had a mass of 27.3 grams giving it a weight of 268 millinewtons in air and 113 millinewtons in water. Burst rates for the MCFT-3A-LAT1400 tags were programmed with a burst rate of 5 s.

Latex tubing was used to reduce tag regurgitation for the gastric implants. All fish were allowed to recover following the tagging procedure and then released via a transport truck directly into the river approximately 0.6 km downstream from the trap entrance at the Merwin boat launch. Due to the limited number of tag frequencies available for transmitters, transmission frequency was changed between 2015 and 2016 fish to reduce the likelihood of picking up similarly numbered transmitters from previous years.

### *Spatial design*

During spring 2016, 18 detection arrays (5 underwater; 13 aerial) were deployed in combinations with receivers (19 SRX800D and 1 Lotek SRX800MD) (Table 3). The receivers had the ability to store approximately 1 million records each. The underwater dipole antenna configuration was constructed with coaxial cable. Site locations in 2016 were nearly identical to those used in 2015 (Table 3), with the exception of an additional antenna that was placed in the fish hopper (Hopper) to provide information that would help (1) discern if and when fish were behaving in response to crowder operations, and (2) evaluate differences in behaviors at successive points along the trap. Aerial antennas were placed in less constrained sites in the downstream and tailrace regions, as well as at the approach to the trap (Figure 2). Aerial antennas were generally placed to achieve a detection area of approximately 10 to 150 m in size in the lower river and tailrace, whereas trap antennas (i.e., Hopper, Pool 1-4, Pool 1-2, and ENT) were placed underwater to provide information for fine scale behaviors and generally had a much smaller detection area of ranging from 5 to 10 m in size (Figure 3).

**Table 3.** Antenna locations, abbreviations, types, antenna number. AR = aerial antenna; UW = underwater antenna.

| Site Abbr | Region; Location | Receiver, antenna element type** | Configuration |
|---|---|---|---|
| BBL | Downstream: Bed and Breakfast ("Bed and Breakfast") | AR, 6 | Perpendicular to the river. Elements are oriented vertically. |
| LRH | Downstream: Lewis River Hatchery ("Hatchery") | AR, 6 | Perpendicular to the river. Elements are oriented vertically. |
| BLD | Downstream: below Merwin boat ramp ("Boat Ramp") | AR, 6 | Perpendicular to the river. Elements are oriented vertically. |
| BLU | Downstream: Holding Pool ("Holding Pool") | AR, 6 | Perpendicular to the river. Elements are oriented vertically. |
| BRG* | Tailrace: below bridge ("Bridge") | AR, 3 | Four (4) 3-element antennas, distributed evenly along the north-south axis of the Merwin bridge, hanging under the Merwin bridge roadway. Elements are facing vertically; downwards from the bottom of the BRG toward the river and parallel to the bridge. |
| SS-S | Tailrace: left bank ("South Shore") | AR, 3 | Perpendicular to the tailrace slight downstream towards the BRG. Elements are oriented vertically. |
| SS-L | Tailrace: left bank ("South Shore") | AR, 8 | Facing downstream towards the BRG to cover the south side of the tailrace. Elements are oriented vertically. |
| NS-S | Tailrace: right bank ("North Shore") | AR, 3 | Pointed straight just in front of the powerhouse. Elements are oriented vertically. |
| NS-L | Tailrace: right bank ("North Shore") | AR, 8 | Facing west towards the Bridge. Angled slightly down towards the water from the deck. Elements are oriented vertically. |
| PWS | Tailrace: along powerhouse wall ("South Powerhouse Wall") | AR, 3 | Pointed towards the powerhouse and slightly angled down towards the water. Elements are oriented vertically. |
| PWN | Tailrace: along powerhouse wall ("North Powerhouse Wall") | AR, 3 | Parallel to the powerhouse and angled slightly down towards the water. Elements are oriented vertically. |
| GAL | Tailrace: gallery behind dam ("Gallery") | AR, 3 | Facing west towards the powerhouse. Elements are oriented horizontally. |
| APR | Approach: in front of trap ("Approach") | AR, 3 | Pointing straight down towards the entrance of the trap. Elements are oriented vertically; parallel to the walk way. |
| ENT | Immediately inside of trap: ("Entrance") | UW, 2 dipoles | 2 – 8259 antennas (deep and shallow), combined at 9211 run out. Antenna is attached to a steel wire rope that is has 80lbs of lead weight attached. |
| PL2 | Trap: pool behind entrance ("Pool 1-2") | UW, dipole | 1 – 8259 dipole antenna attached to fishway wall with Hilti concrete bolts. |
| PL4 | Trap: pool before HOP ("Pool 1-4") | UW, dipole | 1 – 8259 dipole in antenna combined just above the Pool 1-4 waterline. Antenna installed inside ¾ inch schedule 80 conduit, attached to fishway with Hilti concrete bolts |
| HOP | Trap: hopper pool ("Hopper") | UW, 2 dipoles | 2 - 8259 dipole antenna combined at tailrace deck. Each antenna has 2lbs of weight attached. Two (2) underwater cables are bolted along the east and west walls of the |

| Site Abbr | Region; Location | Receiver, antenna element type** | Configuration |
|---|---|---|---|
| | | | hopper. |
| TRP | Captured: trap processing facility (pre-sort pond) ("Trap") | UW, dipole | 1-8259 dipole antenna. Antenna has 0.5lbs lead weight attached. Antenna is positioned at the entrance to the crowding pool next to the fish facility. |

*amplified. **All 3-element antennas were Telonics RA3 yagi with 6 dBd gain. 6-element antennas were Laird PLC1666 with 9 dB gain. 8-element antennas were Telonics RA-4B with 11.8 dBd gain. UW dipole antenna was constructed with Belden RG-58/U #8259 and #9211.


**Figure 2.** Merwin Dam tailrace area with locations of stationed RT antennas and pictures of select antenna orientations. All RT antennas listed in this figure are aerial, except for the Trap. Details of antennas deployed within the trap are shown on the trap schematic in **Figure 2**. North Shore and South Shore sites comprised two (2) receiver stations each: one (1) each of a short three (3)-element and a long eight (8)-element antenna. These were designed to cover larger areas along the full shorelines from the location where they were deployed (indicated by icon placement) all the way to the bridge. The bridge array (Bridge) comprised four (4) amplified three (3)-element aerial antennas hung equidistantly across the length of the bridge. Receivers North Powerhouse Wall and South Powerhouse Wall comprised one (1) three (3)-element antenna each, pointed towards the powerhouse and angled slightly down.

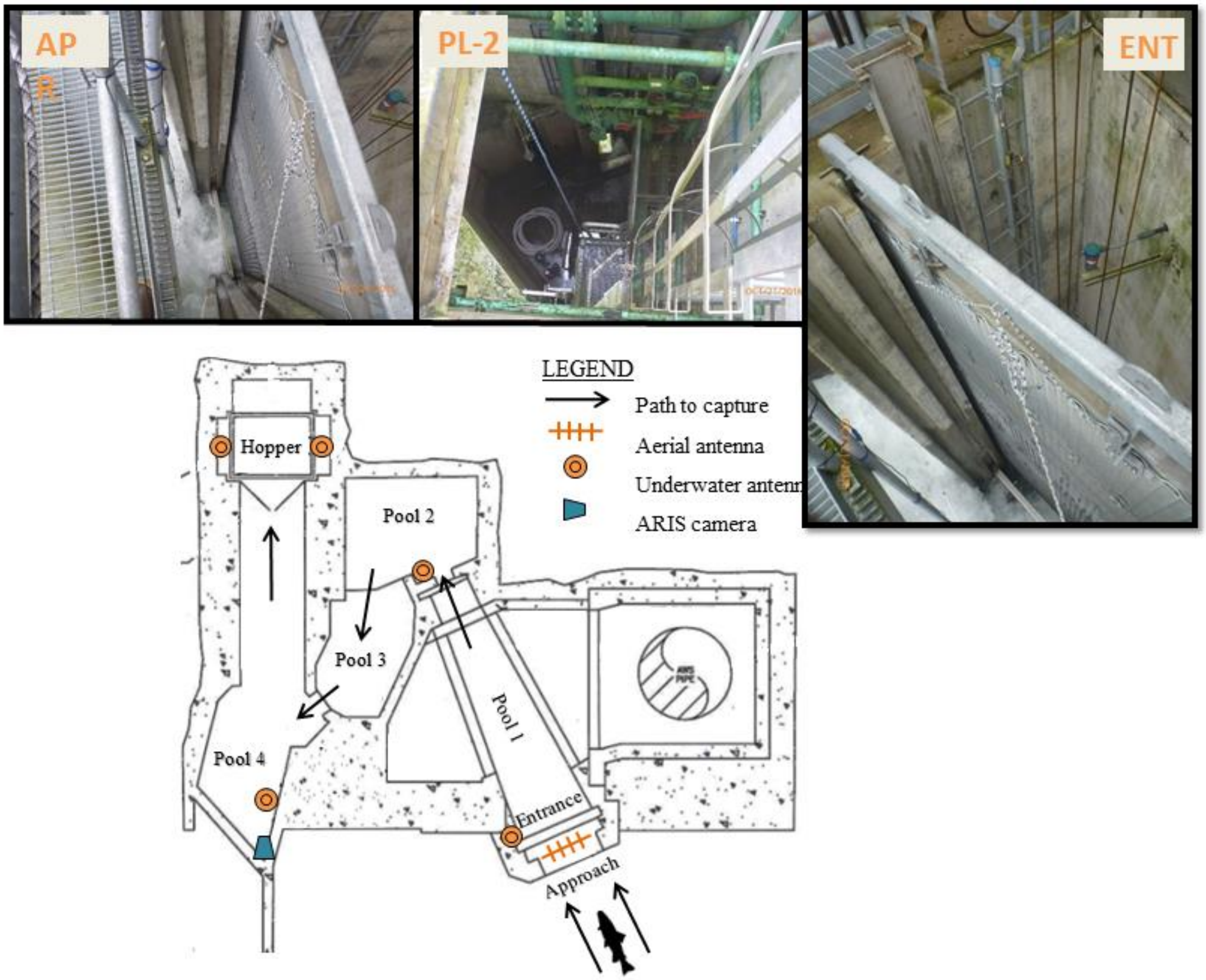


**Figure 3.** Trap schematic showing the locations of antenna arrays, with arrows showing the progressive movements fish make to reach the hopper and pictures of select antenna orientations. The approach is an aerial antenna, and the entrance comprised two (2) underwater dipole antennas located on the left-hand side within Pool 1-1 at two (2) depths. The hopper antenna also comprised two (2) dipole antennas, located outside the path of the ascending and descending hopper. All other trap antennas comprised one (1) dipole depth and one (1) dipole location. After moving to the hopper, fish are crowded and then transported toward the Trap antenna at the fish facility (not shown).

## *Detection capabilities*

Detection ranges were evaluated indirectly during setup optimization and are reported as such. After receivers were constructed and antennas were oriented, detection range was measured in two ways. First, a test tag was held at 1.5m (5ft) depth adjacent to the antenna from a boat that slowly motored away from the antenna, increasing the distance until the tag no longer registered on the receiver. Second, a test tag was held at the limit of a desired detection range (*i.e.*, immediately outside of the range desired) at 1.5m (5ft) depth, and the antenna gain was lowered until the tag was not detected at the receiver.

### *ARIS sonar camera data*

In an effort to better describe fish movement and behavior associated with the fish crowder and conveyance system we installed an ARIS 1800 acoustic camera (soundmetrics.com), mounted on an X2 rotator, near the back wall of Pool 1-4 (Figure 3, Figure 4), from 20 April through 5 May, 2016. The ARIS camera was mounted approximately 1.5 m (5 ft) off the bottom of the pool and 0.6 m (2 ft) under the average water surface level. From this mounting position, the ARIS could accurately record fish movement and behavior in an area approximately spanning the width of pool four from a distance of 3 m (10 ft) in front of the crowder when it was in the fishing position up to the crowder and to a limited degree detect fish behind the crowder. When the crowder was in the closed position (i.e., flush against the hopper door) the ARIS could record fish movement up to the hopper. The ARIS was connected by a data/power cable to a top side box that was located next to the fish elevator shaft and the ladder leading down into the fish ladder facility and powered with nearby line power. The X2 rotator allowed for adjustment of the viewing area from the top side box.

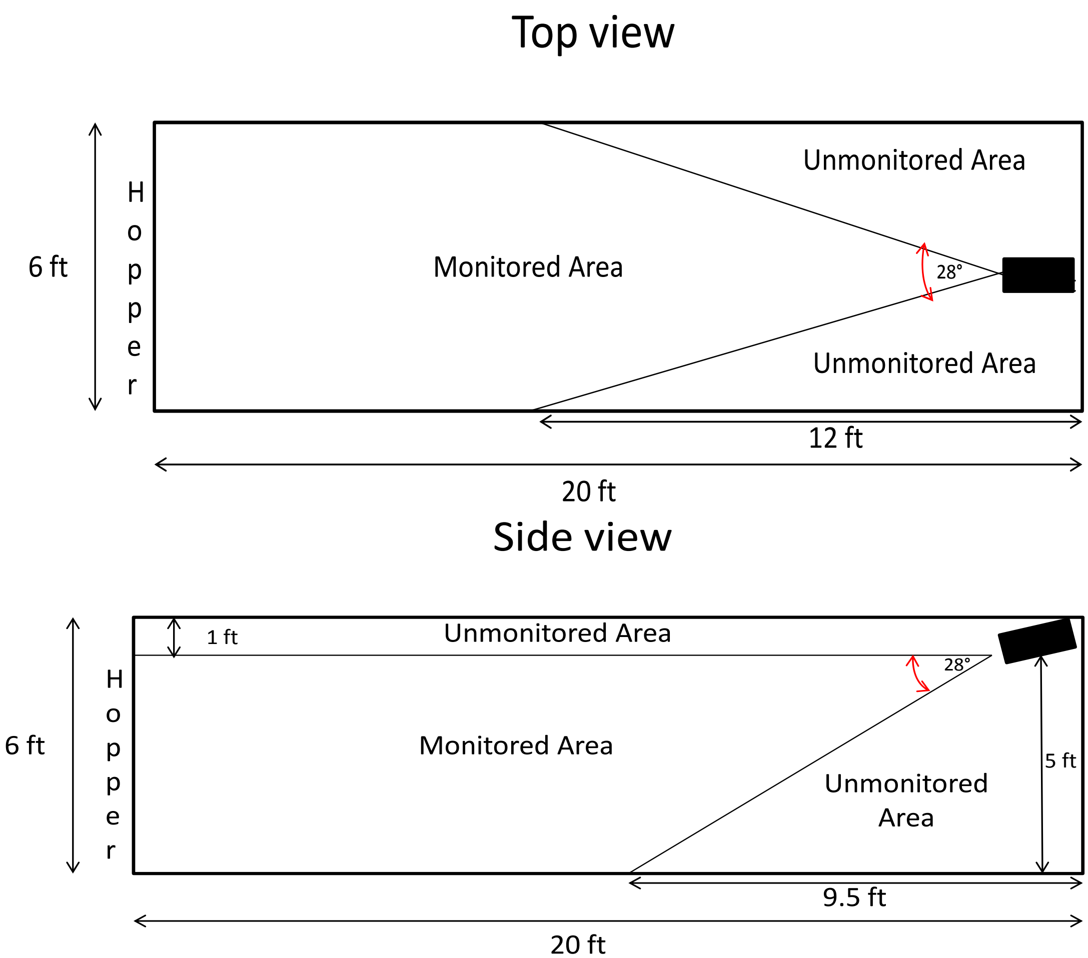


**Figure 4**. Top panel: Top view of beam geometry for ARIS install in Pool 1-4. Bottom panel: Side view of beam geometry for ARIS install in Pool 1-4. (*Note: Figures not drawn to scale.*)

After the initial install, it was evident that the amount of entrained air bubbles being introduced to the fish ladder from the hatchery water pipe was significantly degrading the quality of the imagery. Therefore, on April 21st the flow from the hatchery water pipe was reduced to 50% of capacity. On April 27th flow from the hatchery pipe was reduced to 10% of capacity. Each reduction in flow from the hatchery pipe greatly improved the ARIS imagery.

Data were reviewed for April 20th and 21st and for April 29th through May 5th. Not all data were reviewed and review focused on the latter portion of the recorded data to focus on the best quality imagery, *i.e.*, after hatchery water input had been reduced.

Imagery was analyzed mainly to characterize fish interactions with the crowder. The time of each entry and exit was recorded in addition to the side of the crowder the fish entered or exited. Each crowder reset cycle was also noted along with any fish behavior associated with each reset cycle. Finally, an estimate of the maximum number of fish milling in Pool 1-4 in between each reset cycle was recorded.

## Data Management and Processing

### *Database Construction*

All weekly data downloads were compiled into a single database in order to calculate various metrics associated with the study objectives and operational recommendations. Each week, every site was visited by technicians who checked the sites for malfunctions or clock drift and downloaded receivers. Although receivers were equipped with GPS time correction capabilities, prior to inclusion into the database each file was double-checked and corrected (if needed) for clock drift away from the synced GTM time.

Once raw detection records had been processed, they were compiled into a single MS Access database and queried to remove noise and any tag codes that were not part of our study. Although noise detections are inevitable, receivers were calibrated throughout the season to limit the amount of noise logged by receivers while optimizing tag detectability. After downloads were combined, noise codes were counted, visualized, and removed from the database to provide a coarse estimate of detection efficiency across the study. It should be noted that receivers may also log anomalous tag codes due to signal collisions from multiple tags pinging on the same site simultaneously (126 such cases occurred during 2016), tags from past tracking efforts that remain within the system (mitigated for by tagging at different frequencies during 2015 and 2016), or environmental noise with a frequency near 167 MHz (*e.g.*, dam operations, power transformers, and motor noise from boats or land vehicles).

### *QA Process*

Detection data were subjected to an automated filtration process, developed in 2015 (Stevens et al. 2015), in order to complete the following QA steps:

1) with the exception of the first and last detection per visit, remove consecutive detections at a single site;

2) categorize fish movements in and around the adult trap and bridge (*i.e.,* calculate the total number of exit events that an individual made from the trap or from the tailrace regions); and

3) remove all noise and other detections from non-study fish.

The data filter included the following steps:

- If consecutive detections occurred at the same site and there was a *minimum* of four (4) detections while at that site (*i.e.*, *approximately* 20 s), the first detection was considered the first ("F") time and the final detection was considered the last ("L") time at that site. There were three (3) exceptions to this rule, as follows:
    - At the Bridge receiver, only two (2) consecutive detections were needed, as that site had lowered detectability than other sites due to its unique set-up, suspended from a bridge.
    - At the pre-sort pond receiver (Trap), only one (1) detection was needed to be considered a fish that had been captured successfully, as this location was physically removed from all other sites and it was not possible for a fish to return to the tailrace.
    - At the trap Entrance receiver, four (4) detections were needed *as well as* a minimum signal strength of 160 (Lotek proprietary units) to consider the fish present. The reasoning for this requirement was because this receiver would often pick up fish at lower signal strength and requiring a strong signal, although conservative, provides greater confidence that a fish had passed directly adjacent to the antenna.
- When fish moved among sites, we assumed that the time the fish was first detected at the second location was the start time at the new site, and the previous detection was the last time the fish had been at that site.
- If there were two (2) consecutive detections at the same site but there had been more than a 30-minute difference in the time stamps, this was considered a separate event at the same site, resulting in two (2) consecutive start times at the same location, which results in a single loop in the network analysis at the Entrance receiver (**Figure 11**).
- Fish were assumed to exit the trap when they moved from any of the trap sites inside the fish ladder (*i.e.*, Entrance, Pool 1-2, Pool 1-4, Hopper) to any of the sites outside the trap (*i.e.*, Approach, Bed and Breakfast, Boat Ramp, Holding Pool, Bridge, Gallery, HRH, North Shore, North Powerhouse Wall, South Powerhouse Wall, South Shore). Exit timing was assumed to occur sometime between the "trap" and "non-trap" detections (*e.g.*, most often the gap between receivers Entrance and Approach), but were coded based on the timing of the first detection outside of the trap.
- If fish were detected moving directly from the inside of the trap entrance to immediately outside the trap entrance receivers (*i.e.*, Entrance→Approach) and the signal strength was stronger at the Approach receiver, then fish were assumed to have left the trap and passed directly under the Approach receiver on their way out of the trap.

- If, however, the signal strength was weaker at Approach than the previous Entrance detection, we assumed the fish had never entered the trap, but was instead detected outside of the trap with a weak first Entrance detection.

## Analytical Approach

### *Objective 1: Determine trap effectiveness based on the ATE metric defined in the M&E plan for each target species, and compare estimates to the ATE performance standard of 98%*

The Lewis River Settlement Agreement defines adult trap efficiency (*ATE*) as the percentage of adults of a given species actively attempting to migrate above Merwin Dam which are caught in the Merwin fish trap. The Lewis River Settlement Agreement and the Aquatics Monitoring and Evaluation Plan (2016), sets a target ($ATE_{target}$) of 98% for adult fish migrating upstream towards spawning habitat above Merwin Dam. Estimated observations of *ATE* are essentially data points that are used to test whether overall *ATE* for local populations meets $ATE_{target}$. Consequently, these estimates of *ATE* are referred to as $ATE_{test}$, and are calculated as described above (Equation 1).

Two metrics ($ATE_{test}$ and $P_{EE}$) have been developed in order to evaluate trap efficacy. $ATE_{test}$ is an estimate of overall population level *ATE*, and is calculated as the proportion of fish entering the Merwin Dam tailrace (*M*) that were ultimately captured at the trap (*C*). $ATE_{test}$ is calculated as follows:

$$ATE_{test} = \frac{C}{M}, \qquad (Equation\ 1)$$

where:

*M* is the number of actively migrating fish that enter the Merwin Dam tailrace, determined by unique detections from the tailrace detection sites at or above the access bridge (0.1 km downstream of Merwin Dam) which is downstream of the entrance of the fish trap, and

*C* is the number of fish successfully captured (*i.e.*, successfully passing through the fish crowder/conveyance system and entering the presort pond), determined by unique detections from the trap and any manually collected tags from the collection facility or during fish sorting minus dead or mortally wounded fish or those collected after a specified time period.

An additional metric, trap entrance efficiency ($P_{EE}$), quantifies the proportion of fish entering Merwin Dam tailrace (*M*) that successfully pass the trap entrance (*T*), calculated as follows:

$$P_{EE} = \frac{T}{M}, \qquad (Equation\ 2)$$

where:

*T* is the number of fish that enter the trap, determined by detections at any of the trap entrance, pool, or hopper receivers, and

*M* is the same as defined for Equation 1, above.

A large relative difference between $P_{EE}$ and $ATE_{test}$ would thus reveal ineffective trapping and suggest an operational or infrastructural weak link in upstream passage at the trapping device. Here, we define an additional metric ($T_i$) to quantify trap ineffectiveness. $T_i$ is calculated as the relative proportion of fish that were attracted to the trap entrance, but were not ultimately trapped, and greater values of this metric represent an increasing lack of trap efficacy:

$$T_i = \frac{T-C}{T} . \qquad (Equation\ 3)$$

In order to statistically evaluate whether the observed collection efficiency ($ATE_{test}$) for each species differed from the $ATE_{target}$ of 98%, we undertook two exercises involving randomization and bootstrapping (Manly 2011; Manly 2007). First, we calculated a 95% confidence interval (95% CI) for the 2016 $ATE_{test}$, using iterated random subsampling with replacement (bootstrapping). Our method focused on calculation of the bias-corrected and accelerated 95% confidence interval (BCA 95% CI) (Blank 2009), and included resampling with replacement (*i.e.*, bootstrapping) the set of 128 steelhead that entered the Merwin Dam tailrace (*M*), 94 of which were captured at the trap and were successfully captured (*C*). Manly (2007) recommends ≥5,000 randomizations for bootstrapping exercises to estimate a CI. In the interest of statistical conservatism, we randomly bootstrapped the dataset for one million (1,000,000) iterations, using the Resampling Stats add-in package (Blank 2009) for Microsoft Excel. Simulated $ATE_{test}$ values (*i.e.*, $ATE_{sim}$) were generated for each iteration, and from this set of one million simulations, we then calculated BCA 95% CI, and generated a histogram of simulated frequencies. To estimate the likelihood that the sample of tagged fish actually reached the target *ATE*, we then compared this BCA 95% CI with the target value of 98%, and also calculated the frequency of occurrence of the 98% target among these simulations.

Next, using Program R (R Core Team 2016), we modeled a population of fish that truly exhibited 98% passage (the "urn"), and randomly subsampled groups of 128 fish from this urn to generate iterative simulations of *ATE* ($ATE_{sim}$). For each member of this pool of randomized subsamples, we then calculated the difference between $ATE_{sim}$ and $ATE_{target}$, and generated a frequency distribution for these simulated differences. From this frequency distribution, we then estimated the likelihood that a group of 128 test fish exhibiting the $ATE_{test}$ observed in 2016 and reported here could have come from a parent population that actually exhibited an *ATE* of 98%. This urn simulation can be summarized as follows:

1) Construct a simulated dataset such as would be observed under target conditions of comparison (*i.e.*, 98% passage efficiency), for a population of 10,000 fish[4].
2) Randomly subsample 128 test fish (*i.e.*, to match *M*, the number of tagged fish that entered the Merwin Dam tailrace during the 2016 study) from this overall population of 10,000 fish exhibiting 98% successful passage.

[4] *NB: drawing from an urn population of 10,000 fish ensures two decimal precision (i.e., 9,800/10,000 = 98.00%) associated with modeled passage success among the simulated urn population; drawing from an urn population of 1,000 fish would generate one decimal precision (i.e., 980/1,000 = 98.0%), and drawing from an urn population of 100 fish would generate zero decimal precision (i.e., 98/100 = 98%).*

3) Determine passage efficiency ($ATE_{sim}$) for the subsample iteration.
4) Repeat one million iterations of steps 2 and 3.
5) Calculate the frequency of occurrence for each possible outcome.
6) Determine the frequency of the observed $ATE_{test}$ within the pool of simulated $ATE_{sim}$ values.

To determine seasonal trends in passage rates, an Analysis of Variance (ANOVA) was used to compare $ATE_{test}$ among release groups. Residual and normal probability plots were examined to confirm that data conformed to test assumptions, and a linear regression with a best-fit equation was constructed to visualize the data.

Because fish appeared to enter the trap at higher rates than at which they ultimately were captured, we report on the proportion of entry efficiency at the trap ($P_{EE}$), in addition to $ATE_{test}$. $P_{EE}$ was calculated as described above (Equation 2).

## *Objective 2: Determine if fish show direct movement to the trap entrance and, if some fish do not, document the behavior patterns for those specific fish in the tailrace*

Network (graph) theory was applied to conceptualize, visualize and analyze fish movements within the tailrace (Wilson 1996). Network theory provides a simple, intuitive method for conceptualizing, visualizing, and analyzing fish movement data—particularly as they relate to fish passage issues. All detections zones were represented as nodes (*i.e.*, vertices) and the movements of individual fish between detection zones were represented as directed connections (*i.e.*, edges) between nodes. After being subjected to the QA process described above (*QA Process*), movement patterns were then analyzed both visually and quantitatively.

The raw transition data were modified in several ways, based on dividing the study area into three (3) distinct zones: downstream, tailrace, and trap. The Bridge receiver separated downstream nodes from tailrace nodes, and the Entrance receiver (just inside the fish ladder entrance) separated tailrace nodes from trap nodes. Using these logical labels, the transition matrix created from the raw transition data was adjusted in the following ways:

- Downstream transitions were linearized.
    - (Bed and Breakfast→Holding Pool) became (Bed and Breakfast→Hatchery; Hatchery→Boat Ramp; Boat Ramp→Holding Pool).
- Transitions from downstream to tailrace had their downstream section linearized.
    - (Boat Ramp→South Powerhouse Wall) became (Boat Ramp→Holding Pool; Holding Pool→Bridge; Bridge→South Powerhouse Wall), and likewise for the reverse.
- Transitions from the tailrace to the trap were forced to go through receiver Entrance.
    - (North Shore→Pool 1-4) became (North Shore→Entrance; Entrance→Pool 1-4), and likewise for the reverse.

- Transitions from downstream to trap were not altered since it is not possible to infer how the fish went through the trap zone. Linearizing the path to receiver Bridge, and then forcing them to enter the post through receiver Entrance would create multiple false transitions since we do not know what happened in the trap.

Following construction of the transition matrices, network diagrams representing the study area were generated for visual analysis. In general, thickness and color of edges representing fish movements are weighted such that thicker, darker lines indicate a larger weight. However, edges are not weighted the same way in all diagrams, and the specific weighting scheme used in each network diagram is described and reported in each figure caption.

To analyze fish movement behavior, we discuss and compare several metrics including the following:

- overall passage rates (final fate);
- individual ($P_{single}$) and instantaneous ($P_{all}$) transition rates;
- the difference between individual and instantaneous transition rates, which we define here as the milling index, *MI*

$$MI = P_{all} - P_{single} \; ; \qquad \text{(Equation 4)}$$

- the most probable paths for fish that were ultimately trapped or not trapped using a heat map; and
- the number of sites visited by each fish before exiting the system.

### Objective 3: Determine if fish in the tailrace spend the majority of their time in the area of the entrance of the trap and, if some fish do not, determine if those fish are holding in another location within the tailrace

The amount of time spent at a site before transitioning to a new site (*i.e.*, residence time) was recorded for each site to determine both the amount of total time spent in the site and the median residence time. We constructed box and whisker plots to analyze:

1) Median residence times per site; and

2) Total time spent by each species per site for tailrace and downriver sites.

Precise detection ranges were not available for each receiver, and thus it was not possible to normalize the residence times based on the physical setup of each site. The areas of detection for tailrace sites were tuned to provide a detection "curtain" that effectively blankets the study area while avoiding excessive noise from the powerhouse and other dam infrastructure and operations. The downstream sites (*i.e.*, below the Bridge receiver) were constructed so that their relative areas of detection are identical. The goal of both sites was to detect against the north and south walls approximately two-thirds of the way from the bridge upstream of the total length of the distance between the powerhouse (and transformer deck) and the bridge.

### Objective 4: Determine the total time fish are present in Merwin Dam tailrace and compare to ATE performance standards for safe, timely, and effective passage

We determined the amount of time that fish are present in the tailrace to assess attraction rates and the potential for fish delay. The median and range of total time spent in the tailrace was summarized for comparison with the *ATE* standard of median tailrace time less than or equal to 24 hours with no more than 5% of fish taking longer than 168 hours to pass. We estimated the total time spent in any tailrace zone because it was designed to account for fish milling behavior, and to remain comparable with the 2015 report (Stevens et al. 2015).

### Objective 5: Describe the movement and behavior of tagged fish that do not enter or which choose to leave the Merwin Dam tailrace and move back downstream

To describe and compare the movement of fish entering and leaving the trap, we first identified fish that navigated to just inside the entrance of the fish trap (Entrance receiver), but then transitioned back into the tailrace. We then compared the movement and behavior of these fish with the movement and behavior of fish that entered the trap and did not backtrack.

### Objective 6: Determine the condition of fish that are captured by the trap, as a function of rates of descaling and injury

PacifiCorp staff handled trapping and tagging of study fish, and they also conducted fish health assessments prior to tagging. Fish considered in poor condition were disqualified as candidates for tagging. This ensured that the condition of tagged fish did not bias the analyses or their interpretation. A qualitative discussion of fish condition is included in the results for reference.

### Objective 7. Operational Analysis

By normalizing the transition rates for each site, we created an Individual Based Model (IBM) to simulate fish passage through the study area. We modeled fish movement as a Markov-Chain, meaning each transition was determined solely from the current location (*i.e.*, memoryless transitions; no momentum associated with previous direction and magnitude of vector describing the changes between data states). By releasing fish into the simulation model according to the empirical distributions found from the telemetry data, we created a system that generates results that are literally analogous to (*i.e.*, modeled from) the empirical data, rather than assuming a distribution for those empirical observations and modeling from that. We used this simulation model to investigate how alterations to the system affect the number of fish successfully trapped, and how many sites they visited before being trapped. We tested the following four (4) scenarios, each with model runs of 10,000 individuals:

- Control (*i.e.*, model validation): A version of the simulation using the empirical transition rates taken from the data. This model was used to compare against, and to test the Markovian assumption.

- Model 1: Increase transition probabilities for fish moving to South Shore first rather than North Shore (*e.g.*, "what if a guide net was installed to encourage fish to move along the South Shore on their first trip upstream?").
- Model 2: Add a transition from North Shore to Entrance, drawing on the transition probabilities of fish passing at the current trap (*e.g.*, "what if a new trap was installed on the north shore that had equivalent efficiency as the trap on the south shore?").
- Model 3: Changes in operation of the hopper to possibly improve retention and passage of fish that have entered the fish trap. (*i.e.*, increasing the transition rates between the receivers Pool 1-4 to Trap.

### *Objective 8: Evaluate the directional movement of fish at the crowder.*

There were several instances where fish were detected moving cyclically back-and-forth between the Hopper and Pool 1-4, inside the fish trap. This behavior could be explained in one of at least three ways:

1) Fish swimming back-and-forth in a cyclic fashion between the two trap receivers (*e.g.*, true milling or similar stereotypy);
2) Fish holding station between the two antennas, within detection range of both (*i.e.*, triggering simultaneous detections); or
3) Fish swimming up to the Hopper receiver, then retreating in response to trap operations or to status of lift or crowder.

We queried all instances in the radio telemetry database where only one fish was detected at a time between the two receivers that lined up with ARIS data (20 April through 5 May 2016). Next, ARIS data were investigated (see ARIS sonar camera data methods section, above) to see which behavior, listed above, was most likely occurring, and if those behaviors had distinctive patterns that could be applied to other RT detections that occurred outside of the ARIS window.

# RESULTS

## Summary

In 2016, low numbers of spring Chinook and coho salmon returning to the study area prevented inclusion of these species from the current year's study. Consequently, results here focus on winter steelhead, which were all late winter-run blank wire tag (BWT) fish, not Chamber Creek stock.

From 24 February – 20 May 2016, 148 adult winter steelhead (70 females; 78 males, FL = 55 – 92 cm) were collected at Lewis RKM 31.4, implanted with RT tags, and released 0.6 km (0.4 mi) downstream at Lewis RKM 30.8 to continue their immigrations back to the Merwin Dam trap (Lewis RKM 31.4). Of these 148 steelhead, 144 were detected within the study area, 128 were detected re-entering the tailrace, 125 appear to have navigated to the Approach zone immediately outside the trap, 119 were detected at the Entrance receiver demarking entry to the Merwin Dam trap, and 94 (43 females, 50 males, 1 unidentifiable sex) were re-captured at the Merwin Dam Adult Fish Collection Facility and transported upstream and released above Swift Dam (the upper most of the Lewis River Hydroelectric Projects) (Figure 5).

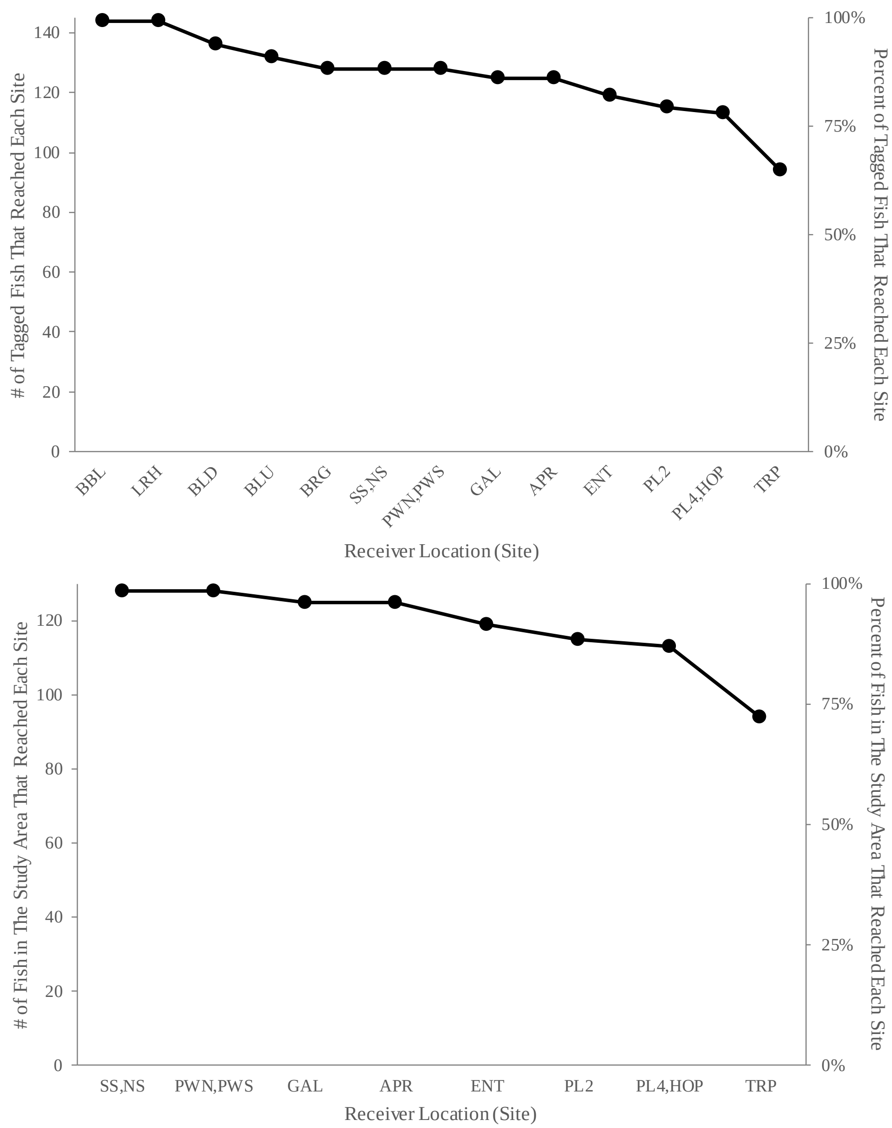


**Figure 5.** Sequence of frequencies of unique fish detected within the Merwin RT array, presented as total number (on left axis) and percentage (on right axis) of all tagged fish entering the study area (top panel) and that subset of fish that entered the Merwin Dam tailrace and were included in subsequent calculations of core passage metrics (bottom panel). See Figure 2 and Figure 3 for receiver locations within the array.

From these counts, core metrics of passage are as follows:

| | |
|---|---|
| $ATE_{test}$ | 73% |
| $P_{EE}$ | 93% |
| $T_i$ | 21% |

Groups of steelhead captured, tagged, and released earlier in the season exhibited higher rates of successful passage than those captured, tagged, and released later in the season (Figure 6). Steelhead captured, tagged, and released after 11 April 2016 generally exhibited a <50% chance of recapture at the Merwin Dam trap.

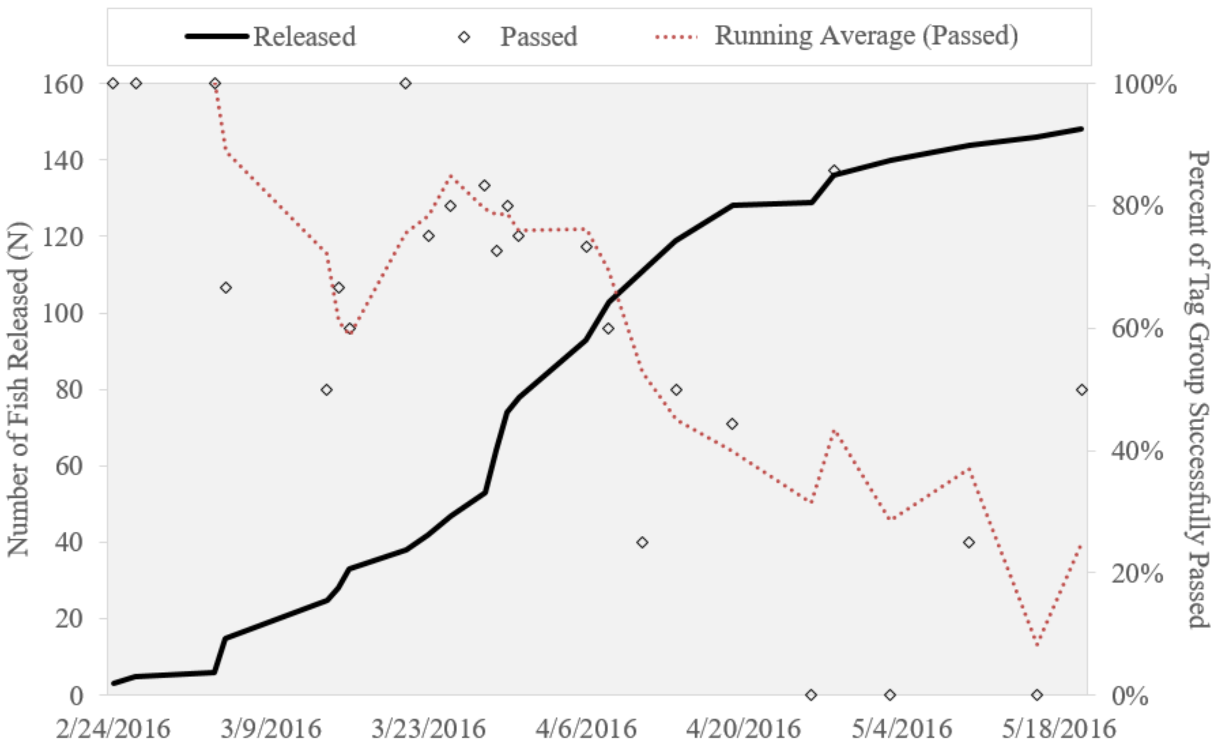


**Figure 6.** Simultaneous time series plots of cumulative count of tagged steelhead (solid black line) and the rate of ultimately successful passage for fish initially captured, tagged, and released on a particular date (open diamonds; 3-date running average of recapture rate shown with dotted red line). Note that adults captured and tagged earlier in the season have higher recapture rates than those captured and tagged later in the season.

# Data Management and Processing

## *Database QA*

There were 4,178,310 detections in the raw data, and 3,909,964 retained detections after the filter was applied.

Noise detections can block an antenna from detecting an authentic transmitter. In this study, noise accounted for 258,795 of total detections (6.1%), a very low value considering the conditions of the study (*e.g.*, a dam tailrace and bridge with occasional car and truck traffic). Noise levels were higher for receivers located at the trap than those stationed in the tailrace (Figure 7). Of the 258,795 noise records, 139,392 (54%) were detected at two (2) sites that were impacted by a pump motor within the trap (Approach and Entrance) (Figure 7). For reasons that may include more tagged fish in the system, more tagging events, or operational patterns, noise levels peaked from 15 April to 5 May (Figure 7). The total number of daily noise detections per receiver remained less than 5,000 by 2 May and less than 1,000 for all receivers by 7 May 2016. The receivers with the most noise hits were: Approach (31% of all noise detections), Entrance (23%), Holding Pool (7%), Pool 1-2 (6%), and South Powerhouse Wall (6%).

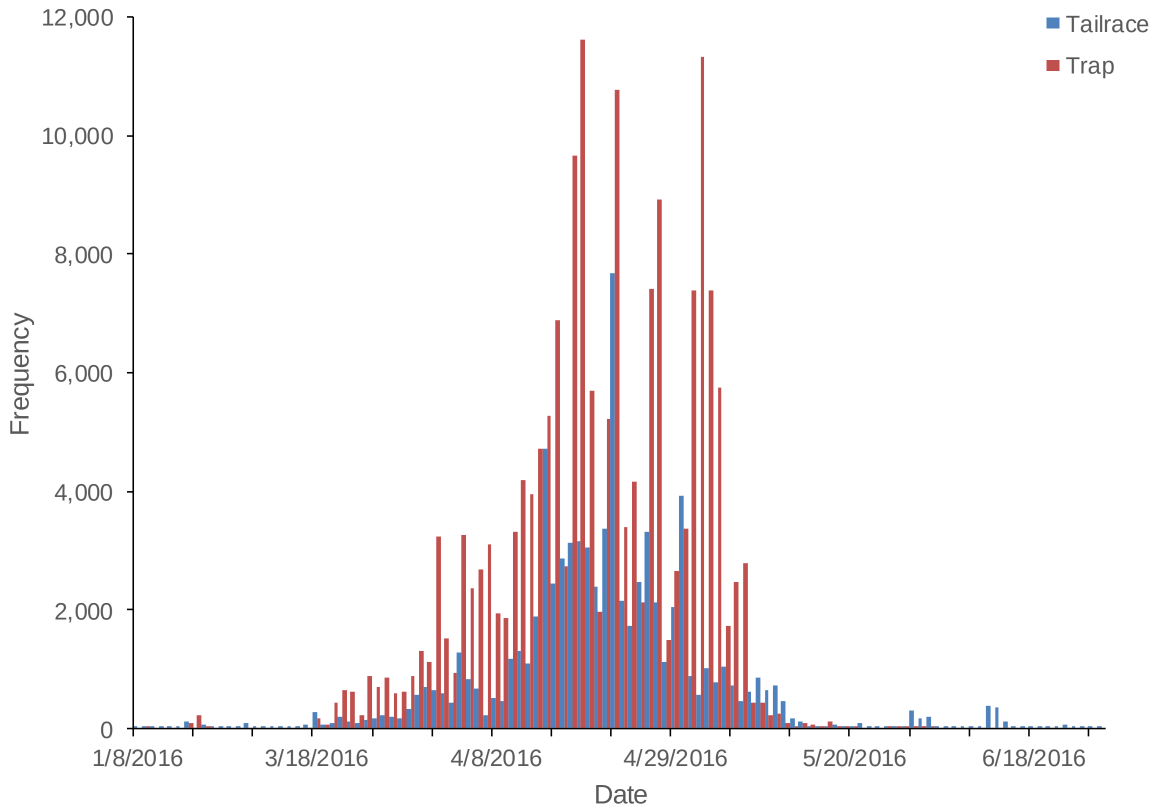


**Figure 7.** Total number of noise detections for trap (red) and tailrace (blue) receivers.

## Objective 1: Determine trap effectiveness based on the *ATE* metric defined in the M&E plan for each target species, and compare estimates to the *ATE* performance standard of 98%

During the 2016 study season, 148 winter steelhead were tagged, of which 144 were detected at least once somewhere within the detection array, 128 were detected within the Merwin Dam tailrace, 119 were detected entering the Merwin Dam trap, and 94 were ultimately captured at the trap. These counts provide the basis for calculation of $P_{EE}$ = 93% (119/128) and $ATE_{test}$ = 73% (94/128; see Table 4, Figure 5).

**Table 4.** Summary of passage metrics for tagged fish approaching the tailrace of Merwin Dam during spring 2016. Total number of fish tagged (*n*), detected in the tailrace (*M*), detected in the trap (*T*), and successfully trapped (*C*), in addition to adult trap entrance efficiency ($P_{EE}$), collection efficiency ($ATE_{test}$) and trap ineffectiveness ($T_i$), for 2016. Fish were considered to have entered the tailrace if they were detected at or upstream of the Bridge receiver. Fish were considered to have entered the trap if they were detected at receivers Entrance, Pool 1-2, Pool 1-4, Hopper, or Trap.

| Metric | Winter Steelhead | Spring Chinook | Coho |
|---|---|---|---|
| Total Tagged (*n*) | 148 | N/A | N/A |
| Entered the Merwin tailrace (*M*) | 128 | N/A | N/A |
| Entered the Trap (*T*) | 119 | N/A | N/A |
| Captured (*C*) | 94 | N/A | N/A |
| Trap Entrance Efficiency ($P_{EE} = \frac{T}{M}$) | 93% | N/A | N/A |
| Collection Efficiency ($ATE_{test} = \frac{C}{M}$) | 73% | N/A | N/A |
| Trap Ineffectiveness ($T_i = \frac{T-C}{T}$) | 21% | N/A | N/A |

Among release groups, $ATE_{test}$ values ranged from 0 – 100% (**Error! Not a valid bookmark self-reference.**) and differed significantly (ANOVA, $df$ = 23; $F$ = 10.742; $p$ = 0.003; Figure 8); $ATE_{test}$ was greater for groups of fish captured, tagged, and released earlier in the season (see Appendix A: Supplementary Figures and Tables for plots of model residuals and tests of normal distribution). During 2016, a substantially higher proportion of winter steelhead found and entered the adult trap ($P_{EE}$ = 93%) compared to steelhead that were ultimately captured ($ATE_{test}$ = 73%). This discrepancy is also reflected by the trap ineffectiveness metric, $T_i$ = 21%, indicating that 21% of fish that entered the trap in 2016 were not ultimately captured.

**Table 5.** Passage metrics summarized by release group for 2016. See **Table 4** for explanation of notation.

| Release Date | *n* | *M* | *T* | *C* | Group $ATE_{test}$ (%) |
|---|---|---|---|---|---|
| 02/24/2016 | 3 | 3 | 3 | 3 | 100% |
| 02/26/2016 | 2 | 2 | 2 | 2 | 100% |
| 03/04/2016 | 1 | 1 | 1 | 1 | 100% |
| 03/05/2016 | 9 | 8 | 8 | 7 | 78% |
| 03/14/2016 | 10 | 9 | 8 | 5 | 50% |
| 03/15/2016 | 3 | 3 | 3 | 2 | 67% |
| 03/16/2016 | 5 | 5 | 5 | 3 | 60% |
| 03/21/2016 | 5 | 5 | 5 | 5 | 100% |
| 03/23/2016 | 4 | 3 | 3 | 3 | 75% |
| 03/25/2016 | 5 | 4 | 4 | 4 | 80% |
| 03/28/2016[5] | 6 | 6 | 6 | 5 | 83% |
| 03/29/2016 | 11 | 10 | 10 | 8 | 73% |
| 03/30/2016 | 10 | 10 | 10 | 8 | 80% |
| 03/31/2016 | 4 | 3 | 3 | 3 | 75% |
| 04/06/2016 | 15 | 13 | 13 | 11 | 73% |
| 04/08/2016 | 10 | 9 | 7 | 6 | 60% |
| 04/11/2016 | 8 | 7 | 6 | 2 | 25% |
| 04/14/2016 | 8 | 6 | 5 | 4 | 50% |
| 04/19/2016 | 9 | 8 | 5 | 4 | 44% |
| 04/26/2016 | 1 | 1 | 1 | 0 | 0% |
| 04/28/2016 | 7 | 6 | 6 | 6 | 86% |
| 05/03/2016 | 4 | 1 | 0 | 0 | 0% |
| 05/10/2016 | 4 | 3 | 3 | 1 | 25% |
| 05/16/2016 | 2 | 1 | 1 | 0 | 0% |
| 05/20/2016 | 2 | 1 | 1 | 1 | 50% |
| **Total** | **148** | **128** | **119** | **94** | ***See Table 4***[6] |

[5] The 3/28/2016 release group includes "Fish 261," which was a mortality due to improper functioning of the crowder door leading to fish becoming stuck beneath the trap. Crowder door operations were corrected by PacifiCorps staff shortly thereafter.
[6] Calculation of mean $ATE_{test}$ across release groups in this fashion is statistically inappropriate and could be misleading. See Table 4 for 2016 $ATE_{test}$ for winter steelhead.

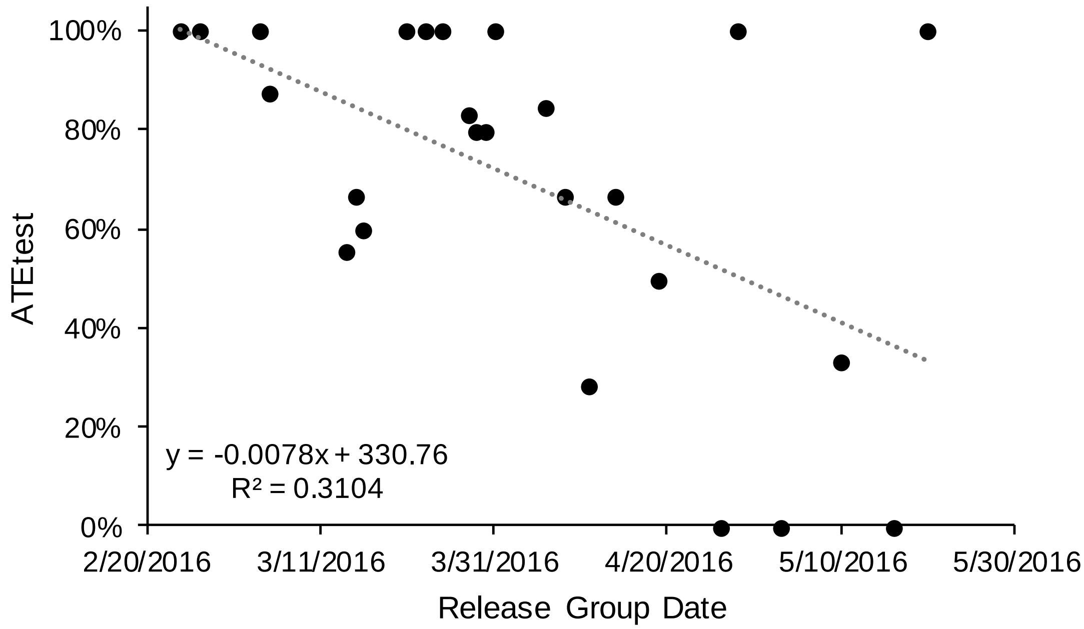


**Figure 8.** The proportion of recaptured fish ($ATE_{Test}$) plotted as a function of release date. Dashed line indicates a least squares linear regression line fit to the data; equation of the line and the $r^2$ value are displayed.

Bootstrapping the fish passage dataset generated a BCA 95% CI (64.8 – 79.7) that converged on stable estimates when the total number of randomized resampling iterations was greater than 1,000 (Figure 9). From this exercise, we draw two conclusions: First, the calculated $ATE_{test}$ for 2016 can be contextualized appropriately: based on random subsampling of the overall sample of fish observed in the current study, we are 95% confident that, for 2016, 64.8 < $ATE_{test}$ < 79.7% for Lewis River winter steelhead approaching and attempting to pass Merwin Dam. Notably, when the sample of fish that reached Merwin Dam tailrace was iteratively subsampled one million times, the target *ATE* of 98% was reached zero times.

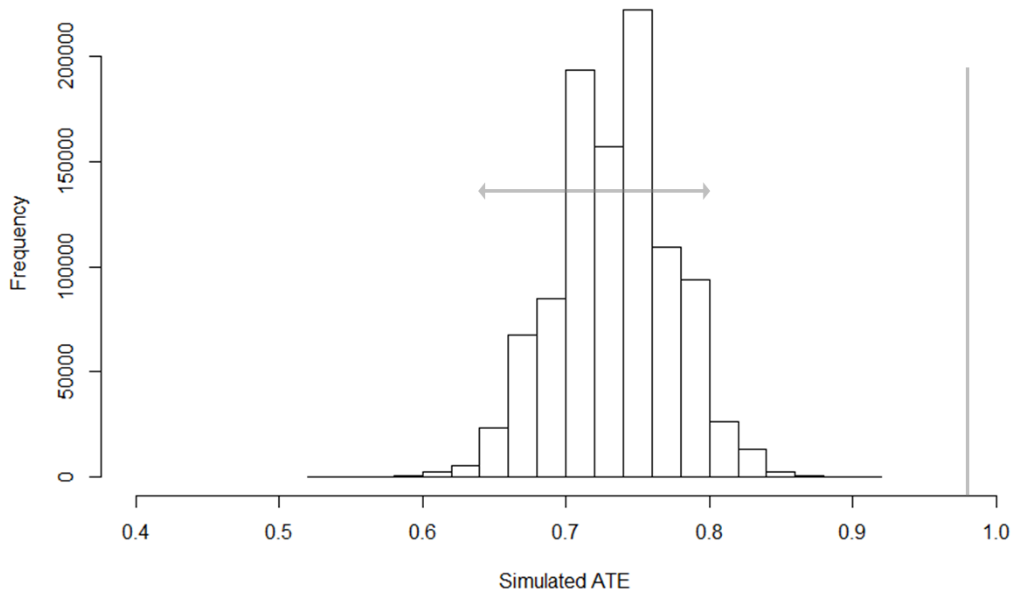


**Figure 9.** Bootstrap simulated frequencies of *ATE* calculated from one million iterations of randomly resampling (with replacement) the sample of 128 fish that reached the Merwin Dam tailrace. Horizontal bi-directional gray arrow indicates BCA 95% CI (64.8 – 79.7%); vertical gray line indicates target *ATE* of 98%. Note that target *ATE* was reached in zero of one million simulations.

Next, in order to quantify the likelihood that the population of Lewis River winter steelhead spawning above Merwin Dam (*i.e.*, attempting to pass Merwin Dam) may actually have exhibited *ATE* = 98%, even though our observation was only $ATE_{test}$ = 73% (based on tagged fish that entered the Merwin Dam tailrace), we conducted an urn simulation. When simulated subsamples of 128 fish were drawn from a parent population that actually exhibited 98% *ATE*, zero out of one million simulated subsamples exhibited $ATE_{sim}$ as low as 73% (Figure 10). Among this set of one million $ATE_{sim}$ values, the lowest was 89.8%.

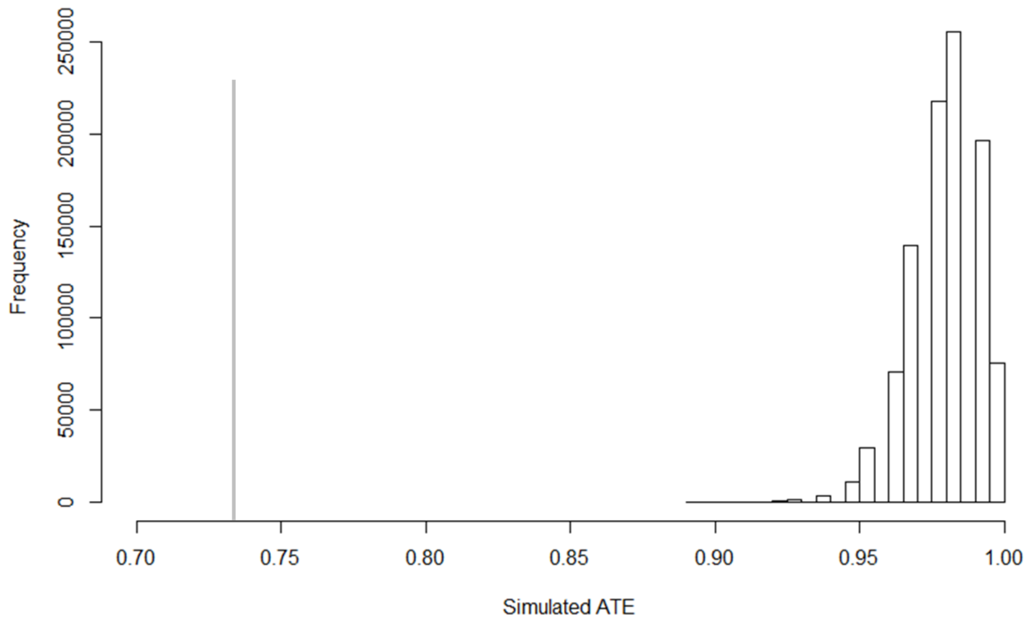


**Figure 10.** Simulated frequencies of *ATE* calculated from one million iterations of randomly subsampling a set of 128 fish from a simulated "urn" population of 10,000 fish that truly exhibited 98% *ATE*. Vertical gray line indicates observed $ATE_{test}$ of 73%. Note that $ATE_{test}$ reported here for 2016 was reached in zero of one million simulated subset samples of 128 fish from the parent population of 10,000.

## Objective 2: Determine if the fish show direct movement to the trap entrance and, if some fish do not, document the behavior patterns for those specific fish in the tailrace

A visual analysis of the network diagram for winter steelhead movements throughout the study area illustrates the tendency of fish to move widely within the tailrace (Figure 11). Key findings include:

1) Fish entering the tailrace upstream of the Bridge receiver most commonly head north to the North Shore, rather than moving along the South Shore(the darkest grey lines leaving Bridge in Figure 11). A smaller proportion of fish first enter the tailrace from Bridge and then head south to South Shore (Figure 11).
2) The most frequent pathway that resulted in a detection at the approach to the trap was from the South Shore (the darkest grey lines pointing towards Approach in Figure 11).
3) Individuals exhibit milling behaviors (blue lines) most commonly on the south side of the tailrace, between receivers South Shore↔ South Powerhouse Wall, South Powerhouse Wall↔ Approach, Entrance↔ Approach, and Pool 1-2↔ Entrance (Figure 11). There is relatively less milling that occurs between North Shore↔ North Powerhouse Wall.
4) Within the trap, the majority of milling occurred between Hopper ↔ Pool 1-4 (Figure 11).

Next, we generated a heat map in matrix form depicting color-coded probabilities of fish moving from one site to another (Figure 12). Within this figure, a stair-step pattern is apparent from the upper left to the bottom right, suggesting that fish are generally moving sequentially up through the system, but that there is not one clear pathway that ends just inside the trap entrance, (Entrance receiver). Other insights that emerge from the heat map figure include the following:

1) Once a fish has progressed up to the site Bridge, it has a probability of 0.1 – 0.6 of next being detected at one (1) of six (6) receivers with the tailrace up to (.
2) Once a fish has nosed into the trap at the receiver Entrance there are ten (10) next potential locations a fish will be detected, the most likely of which (with 0.6 probability) is outside of the trap at Approach.
3) Once inside the trap and detected in ladder Pool 1-2 there are five (5) next potential locations at which a fish will be detected. The most likely (with a probability of 0.8) is further downstream at the Entrance receiver.
4) Once inside of the trap, there are many potential next sites that a fish utilizes, which suggests either that fish are not following a clear directional path once inside, or that antenna detection zones overlap.

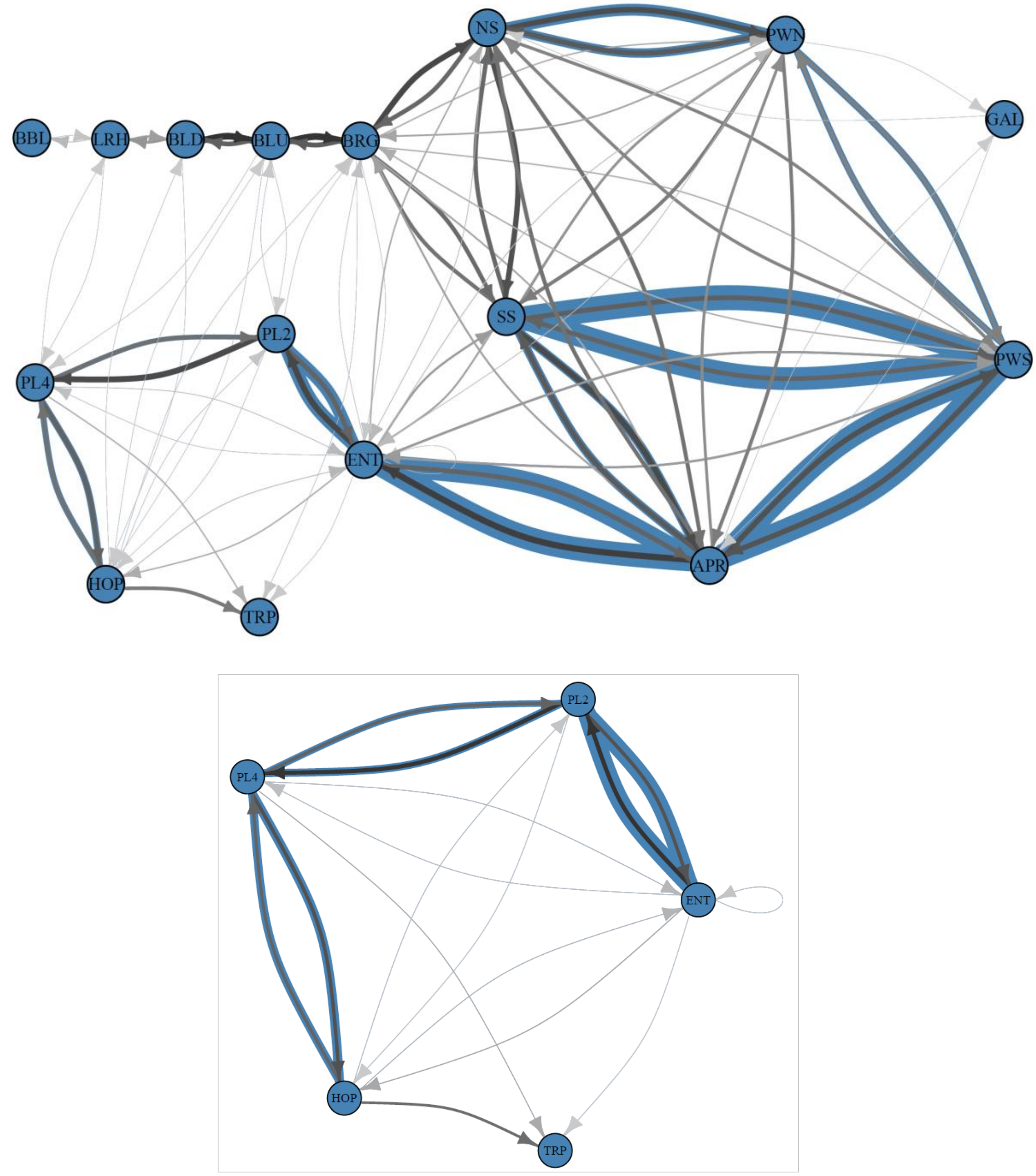


**Figure 11.** Network diagram of fish movement within study area. Path thickness and color are scaled based on the total number of individual fish traveling the paths (*e.g.,* thicker paths represent a higher number of fish taking the path at least one time across their detection history). Grey paths are scaled to represent the total number of fish that traveled between sites (individuals as the sample unit), and blue paths are scaled to represent the total number of times that a path was used (total number of behaviors, with movements as sample units; *non-independent*). Top figure shows all sites; bottom figure shows only trap sites and includes re-normalized transitional probabilities calculated using detections at trap sites only.

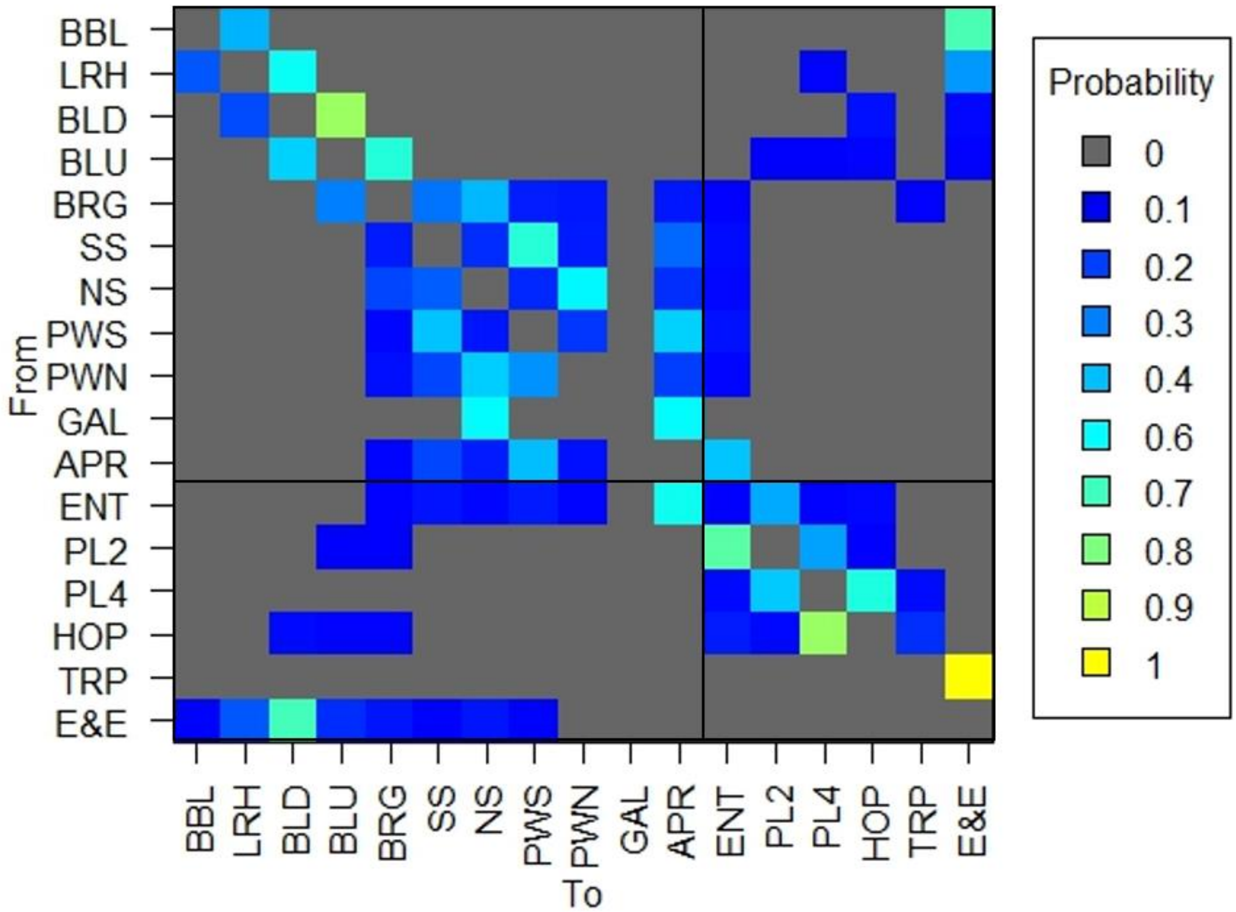


**Figure 12.** Heat map of the transition probabilities of fish moving from an origin site to all potential destination sites, where each row sums to a probability of 1.0. The black reference lines are added between the receivers Approach and Entrance to show the distinction of a fish being located within or outside of the trap. Probabilities in the upper left box represent movements that begin and end in the river or tailrace, while those in the bottom right begin and end in the trap. Probabilities in the upper right box represent paths that begin in the river or tailrace and end in the trap, and the lower left box begin in the trap and end in the river or tailrace (*e.g.* exiting the trap). E&E represents entrance and exit locations from the study system. For example, fish that are at the Trap always exit the system (*e.g.,* they cannot leave), so there is a probability of 1.0 at the Trap row and E&E column).

By comparing the number of sites visited by each fish (Figure 13), it is apparent that fish do not tend to move directly into the trap. More than half of the fish that were eventually trapped had visited 100 or more sites before being trapped.

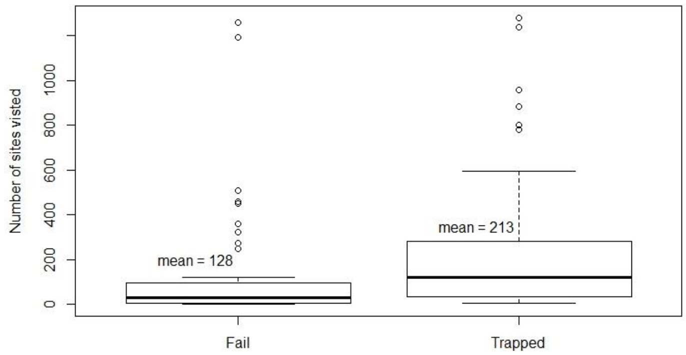


**Figure 13.** Number of sites visited before being captured (Trapped) or not captured (Fail).

In general, fish tended to move forward through the study site between Boat Ramp and North Shore, with most sites having a forward transition probability greater than 50% ($p \geq 0.50$) (Table 6). Fish at Boat Ramp had a 71% chance to transition to receivers other than Bed and Breakfast and Hatchery in their next transition; whereas across all detections 84% of the time that a fish was at Boat Ramp it moved forward in the system during its next transition. Fish at receivers South Powerhouse Wall, North Powerhouse Wall, Approach, Entrance and Hopper all had higher rates of moving backwards in the system, causing them to loop around the tailrace. The three (3) sites with the highest *MI* values (*i.e.,* those where fish milled) were: Hopper, Pool 1-2 and North Powerhouse Wall.

**Table 6.** Probabilities of transitioning further into the system for each site. $P_{single}$ is the probability of a fish transitioning forward to the next most upstream site(s) rather than falling back to the downstream sites. $P_{all}$ is the same probability, across all detections rather than across individual fish. *MI* is a milling index, calculated as the ratio $P_{single}$:$P_{all}$. Values that are positive suggest that fish tend to not move forward from that location. Site specific $P_{single}$ or $P_{all}$ <0.05 are shaded blue, and *MI* >0.000 are shaded green. Hopper site is bolded to note that this site was associated with the highest calculated *MI* (0.300), a value that was 35% greater than the next highest *MI*¸ which was associated with Pool 1-4 (0.221).

| Receiver | $P_{single}$ | $P_{all}$ | *MI* |
|---|---|---|---|
| BBL | 0.353 | 0.353 | -0.000 |
| LRH | 0.463 | 0.527 | -0.064 |
| BLD | 0.709 | 0.838 | -0.129 |
| BLU | 0.589 | 0.583 | 0.006 |
| BRG | 0.753 | 0.747 | 0.006 |
| SS | 0.641 | 0.856 | -0.215 |
| NS | 0.577 | 0.675 | -0.098 |
| PWS | 0.375 | 0.448 | -0.073 |
| PWN | 0.240 | 0.136 | 0.104 |
| GAL | 0.500 | 0.500 | -0.000 |

| Receiver | $P_{single}$ | $P_{all}$ | *MI* |
|---|---|---|---|
| APR | 0.245 | 0.388 | -0.143 |
| ENT | 0.392 | 0.356 | 0.036 |
| PL2 | 0.542 | 0.321 | 0.221 |
| PL4 | 0.546 | 0.580 | -0.033 |
| **HOP** | **0.393** | **0.093** | **0.300** |

When evaluating differences in transition probabilities between trapped and non-trapped fish (Figure 14), there were no clear apparent divergences between the groups in terms of how they moved through the system.

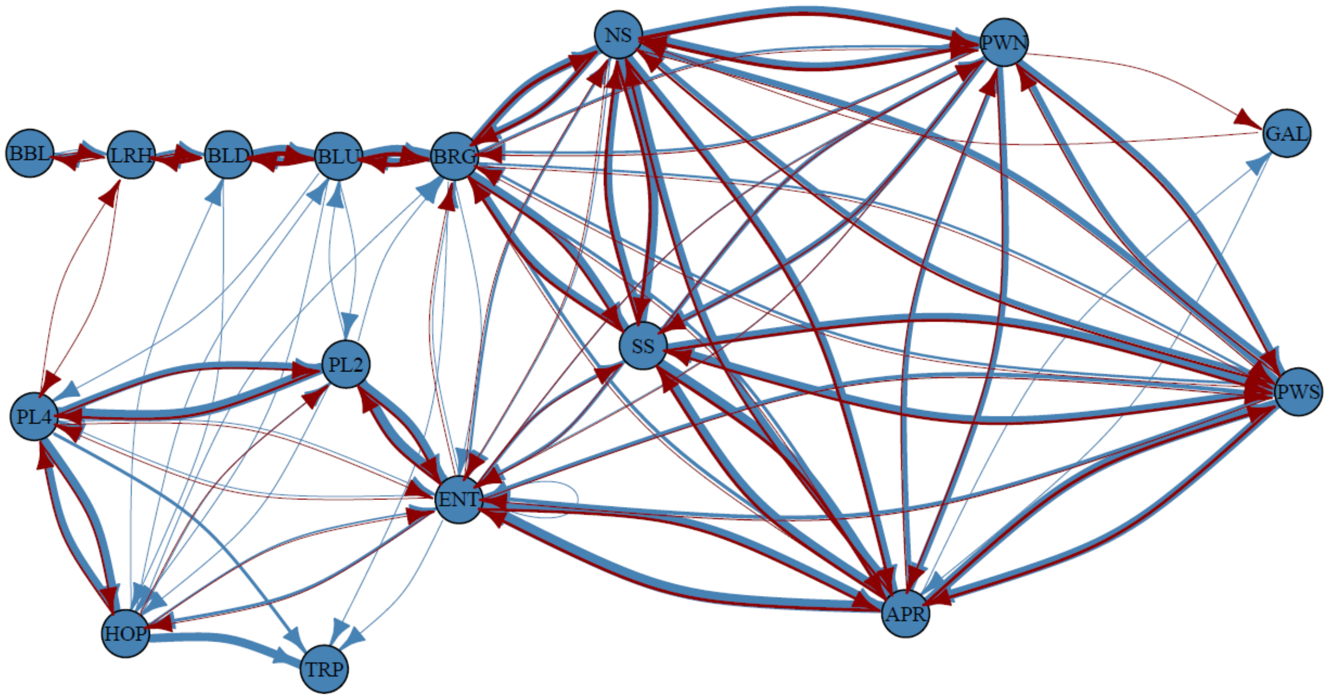


**Figure 14.** Network diagram of fish movement within the study area at Merwin Dam grouped by fish that ultimately are trapped (blue) or failed to be trapped (red) from 2016. Path thickness and color are scaled based on the total number of transitions which occurred between sites with fish as the sample unit. This figure suggests that there are essentially no significant differences in the spatial patterns between successfully and unsuccessfully passed fish in Merwin tailrace. This graphic depicts the movements of 144 fish; 94 that were successfully passed (*i.e.* last detected at Trap) and 50 that were unsuccessful (*i.e.* last detected downriver at Hatchery or Bed and Breakfast).

## Objective 3: Determine if fish in the tailrace spend the majority of their time in the area of the entrance of the trap and, if some fish do not, determine if those fish are holding in another location within the tailrace

In general, once in the study area, fish tended to spend the majority of their time holding and milling at the north side of the tailrace (North Shore) or just outside of the the enerance of the fish trap (Approach) (Figure 15, Figure 16). Evaluation of winter steelhead behaviors within the tailrace revealed the following observations:

1) Fish spent the most time within the north side of the tailrace (North Shore) although fewer fish resided in this detection zone; North Shore has the longest total residence time despite a lower number of visits (*n*), which aligns with the site also having the longest median residence time.
2) Fish visited the Approach site frequently, leading to them spending a large amount of time just outside the the trap enterence, athough this was averaged over multiple visits; Approach has the second longest total residence time, but also more than double the visits compared to North Shore. This implies less holding behavior, and more milling.
3) Fish also frequently visited the South Shore and South Powerhouse Wall zones; South Shore and South Powerhouse Wall also have high *n* values and low median residence times, which implies they are also involved in milling behavior.
4) Fish tended to avoid the North Powerhouse Wall zone, and did not linger while there; North Powerhouse Wall has very short median residence times, the shortest total residence time, and also the least extreme outliers (in both number and magnitude).

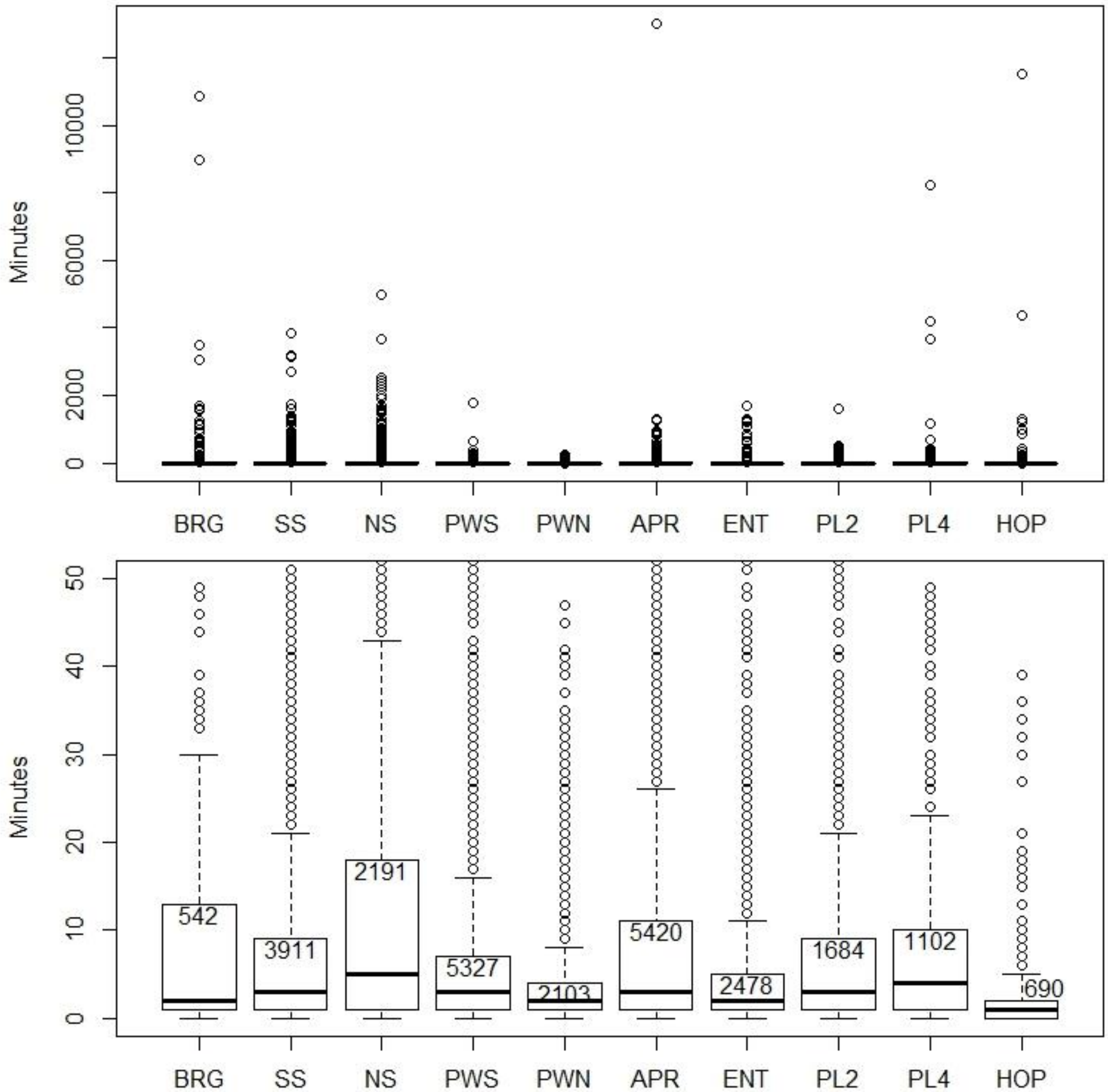


**Figure 15.** Median residence times by site. The top figure shows the full range of datea, including outliers, while the bottom figure zooms in to show the box and whisker plots, focusing on inter-quartile range. Sample size (n) is displayed in the top of the box plots for each site. Caveat: these data are not scaled based on the detection ranges of each site.

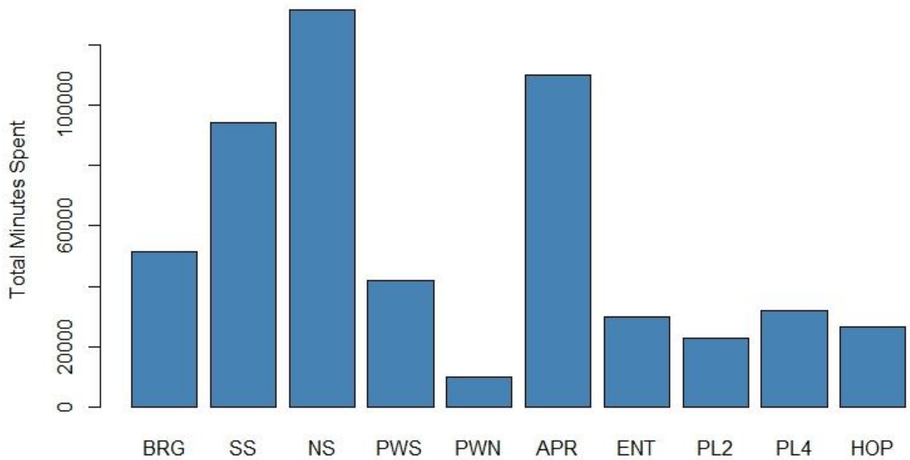


**Figure 16.** Total time spent by all winter steelhead in each site. Caveat: these data are not scaled based on the detection ranges of each site.

At downstream locations, before fish enter the study area above the Bridge, fish appear to move quickly past the Bed and Breakfast location, then hang up near the hatchery (Figure 17). Once past the hatchery, individual fish do not spend an inordinate amount of time near the Boat Launch sites (Figure 17); however, when aggregated across all winter steelhead included in the 2016 study, the Boat Launch does emerge as a potential slow point in up-stream migration (Figure 18).

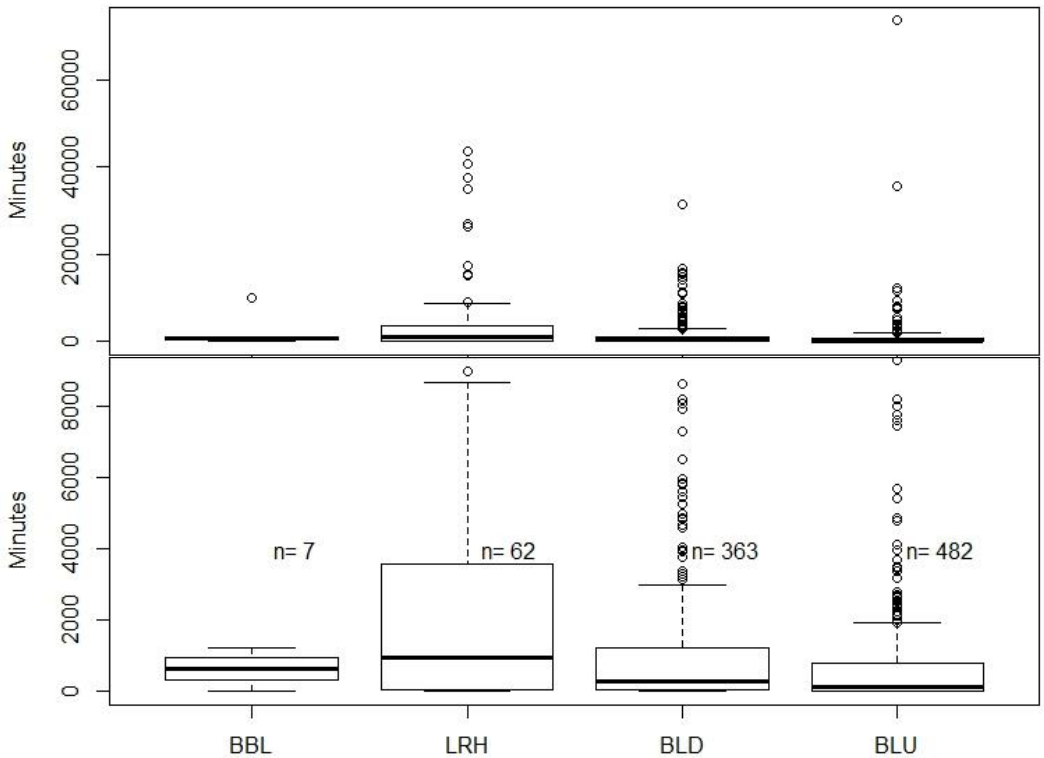


**Figure 17.** Residence times for downriver sites. The top figure shows the full range of data, including outliers, while the bottom figure zooms in to show the box and whisker plots, focusing on inter-quartile range. Sample size (n) is displayed in the top of the box plot for each site. Caveat: these data are not scaled based on the detection ranges of each site.

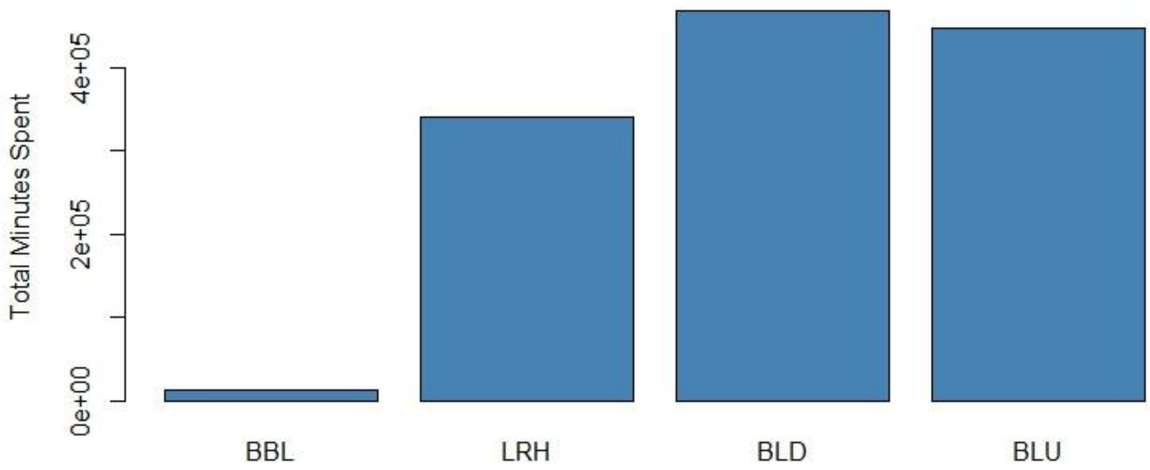


**Figure 18.** Total time spent by all winter steelhead in each downriver site. Caveat: these data are not scaled based on the detection ranges of each site.

## Objective 4: Determine the total time fish are present in Merwin Dam tailrace and compare to *ATE* performance standards for safe, timely, and effective passage

ATE performance standards indicate that safe, timely, and effective passage is associated with median tailrace time of less than or equal to 24 hours, with less than or equal to 5% of fish taking longer than 168 hours to pass. The median tailrace residence time for all winter steelhead in the Merwin Dam tailrace was 29.2 hours, with a range 0.03 – 605 hours. Given fish milling behavior, this may represent total time spent during multiple trips through the tailrace. Only 14 winter steelhead (approximately 10%) had a tailrace residence time greater than 168 hours; the *ATE* standard for safe, timely, and effective passage is a 5% maximum. Thus, both performance standard compliance metrics for tailrace residence time were not net.

Additionally, the following insights were apparent from evaluation of the detection data:

- Nine (9) winter steelhead entered the tailrace but never entered the trap. Within this group, fish exhibited a median tailrace residence time of 2.8 hours (range of 0.15 - 22.73 hours), and zero (0) fish exhibited a tailrace residence time greater than 168 hours, meeting both compliance standards.
- Twenty-five (25) winter steelhead entered the trap but were never captured. These fish exhibited a median tailrace residence time of 47.4 hours, with a range of 0.03 – 576.9 hours. Within this group, only two (2) fish exhibited a tailrace residence time greater than 168 hours.
- Ninety-four (94) winter steelhead entered the trap and were captured successfully. These fish exhibited a median tailrace residence time of 29.2 hours, with a range of 0.75 – 605

hours. Within this group, 12 fish exhibited a tailrace residence time greater than168 hours.

## Objective 5: Describe the movement and behavior of tagged fish that do not enter or which choose to leave the Merwin Dam tailrace and move back downstream

Of the 144 winter steelhead that were detected in the array study area, 128 were detected in the Merwin Dam tailrace (*M*), 119 entered the trap (*T*), and 94 were captured (*C*) (Figure 5, Table 4). Of the 119 fish detected at the trap entrance, 95 (80% of *T*) returned to the tailrace after first visiting the trap. 74% (*i.e.*, 70) of those 95 fish that moved back downstream after their first post-tagging encounter with the trap were eventually captured; the remaining 25 fish were not. This means that 70 out of 94 fish that were ultimately captured had entered and exited the trap at least once after being tagged and released, but prior to being successfully trapped—a 206% greater number compared to the only 24 fish were successfully trapped during their first post-tagging encounter of the trap. In other words, only 20% (24 of 119) of fish that entered the trap continued through and were captured on their first post-tagging encounter with the trap. Also, of the 128 fish detected in the tailrace, 33 (*i.e.*, 26%) returned to downriver sites (*i.e.*, below the access bridge); 17 of these 33 (*i.e.*, 52%) were successfully captured while the remaining 16 fish were not.

## Objective 6: Determine the condition of fish that are captured by the trap, as a function of rates of descaling and injury

Only recaptured radio tagged fish were included in the injury assessment. Including maiden capture fish would likely be erroneous as prior to being trapped fish have traveled long distances and are subject to other sources of injury not associated with trapping operations. Only healthy winter steelhead free of injury were tagged in the study. Once a radio tagged fish was recaptured it was then inspected for injury and any found injuries were assumed to be caused by trapping effects.

Of the 94 radio tagged winter steelhead that were recaptured eight (7) fish were shown to have signs of injury and one (1) fish was a mortality. However, three (3) of the eight injured fish were designated as injuries from tangle netting efforts from a separate study in the Lewis River conducted during the same timeframe as this study and were not included in the injury assessment. Therefore, it was determined that there was an observed trapping injury rate of 4% (4 of 94) for winter steelhead in 2016. Of the four (4) observed injuries one (1) was a caudal peduncle flesh wound, one (1) was greater than 10% descaling on a single side, and two (2) were flesh wounds to the snout. The one (1) mortality was due to a hopper malfunction resulting in the tagged fish getting stuck underneath the hopper in the hopper sump.

# Objective 7: Operational Analysis

We performed four (4) simulations, including a control of the raw transitional probabilities, in order to evaluate which potential scenario would result in the greatest change in *ATE* rates:

*Control*: The control model returned the correct percentage of captured fish (*i.e.*, the model results mirrored the empirical data), but had a larger median number of sites visited (

Table **7**). This is most likely due to aggregating all transitions across all fish. Our model assumes that all fish move equally, while in reality, a few outliers contributed disproportionately high numbers of sites visited.

*Model 1*: To test the effects of directing winter steelhead towards the south shore instead of the north shore, we doubled the amount of transitions between receivers Bridge and South Shore, which made it the most likely transition from the Bridge site. The effect on fish passage was minor (

Table **7**). The average number of sites visited by winter steelhead decreased in this scenario, but the median number increased (

Table **7**).

*Model 2*: To test the effects of installing a trap (or an entrance to a collection channel leading to the current trap) located along the north shore, we increased transition probabilities between the receivers North Shore to Entrance to match the probability of transitioning from Approach to Entrance. This had the effect of sending fish from the North Shore to a trap with efficiency identical to that of the south shore trap. The result of Model 2 simulation show a minor increase in the percentage of trapped fish (approximately 2% increase), and a larger decrease (-14%) in the median number of sites visited (

Table **7**).

*Model 3*: To test the effects of the hopper operating more frequently, we doubled the number of transitions from the receivers Pool 1-4 to Hopper, making it twice as likely for a fish to transition from Pool 1-4 into the hopper. Results from Model 3 indicate an increase in *ATE* of 3.6 percentage points for a simulated *ATE* of 68.9%, representing a 5.5% gain compared to the control scenario. Model 3 also predicts a decrease of 26% in the median number of sites visited (

Table **7**).

**Table 7.** Results from simulation models. *ATE* = adult trap efficacy; AVE = average; MED = median.

| Model | Description | *ATE* | Sites Visited (AVE) | Sites Visited (MED) |
|---|---|---|---|---|
| Raw empirical data | Values from data | 65.3% | 183.26 | 76 |

| | | | | |
|---|---|---|---|---|
| Model Un-modified | Control | 65.3% | 196.7 | 121 |
| Model 1 | Doubles the transitions from Bridge to South Shore | 67.5% | 203.14 | 118.5 |
| Model 2 | Allow North Powerhouse Wall to transfer to Entrance at a similar rate as Approach to Entrance | 67.7% | 169.01 | 104 |
| Model 3 | Double the transitions from Pool 1-4 to Hopper | 68.9% | 146.29 | 89 |

## Objective 8: Evaluate the directional movement of fish at the crowder.

Approximately 183 hours of acoustic telemetry data covering 150 crowder reset cycles during 20 – 21 April and 29 April – 5 May were analyzed. During this time period, 308 fish entries and 300 fish exits were recorded through the crowder while it was in the fishing position. In addition, 51 fish were identified as entering the area behind the crowder while the crowder was in the closed position (flush against the hopper) and then were subsequently trapped behind the crowder as it moved back down Pool 1-4 and into its fishing position. Of the 150 reset cycles, 59 had no fish visible in Pool 1-4 (39.3%), 89 had no indication of a fish response to the crowder movement (59.3%), and only two resulted in fish moving downstream out of Pool 1-4 (1.3%). Eighty-three percent (256/308) of the fish entering the crowder did so from the right hand side (the side nearest the entrance from Pool 1-3). Ninety-four percent (283/300) of the fish exiting the crowder exited to the right hand side. The minimum number of fish milling in Pool 1-4 during a crowder reset cycle was zero and the maximum was four, the average was slightly more than two.

An exploratory figure was constructed showing the timing mismatch between crowder operations and fish that are successfully captured at the Merwin Dam trap (Figure 19).

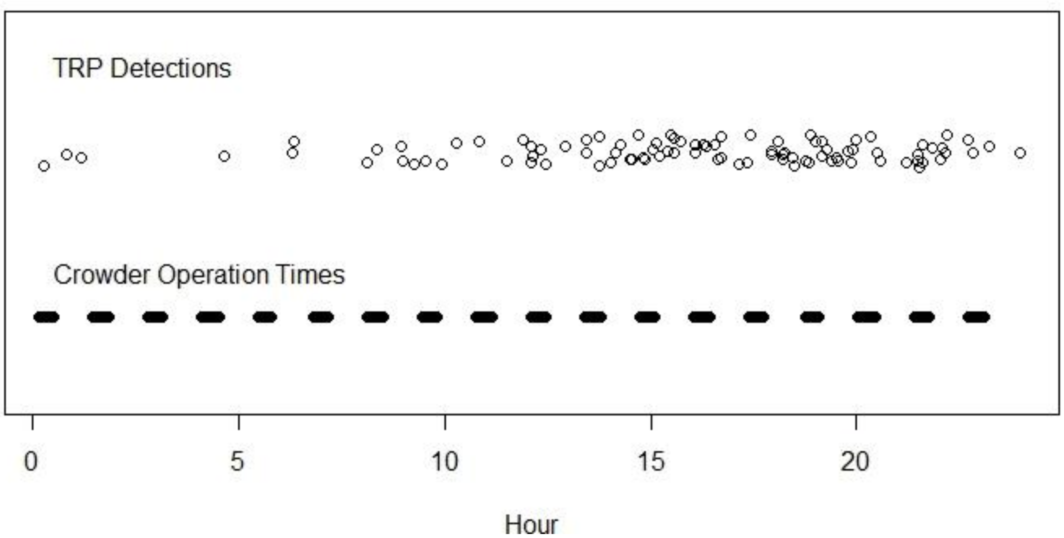


**Figure 19.** Timing of Trap detections for fish captured successfully at the Merwin Trap, as compared to the timing of crowder operations. This figure shows that the majority of fish are passing in the second half of the day (1200 to 2400 hours).

# DISCUSSION

In 2016, 148 winter steelhead were tagged, of which 144 were detected somewhere in the study area, 128 were detected within the tailrace of Merwin Dam, 119 were detected entering the trap, and 94 were successfully captured. During this year, low return numbers for both spring Chinook and coho salmon prevented including those species in the study. As a result, only winter steelhead were evaluated in 2016, and $ATE_{test}$ for winter steelhead is the only value contributing to the study-wide $ATE_{test}$ estimate. Future analytical efforts that include interannual comparisons of study-wide $ATE_{test}$ should take note that the 2016 effort comprises records of winter steelhead only.

$ATE_{test}$ for the 2016 study was 73% (BCA 95% CI = 64.8 – 79.7), and below the 98% target. Moreover, when bias corrected and accelerated (BCA) confidence bounds were bootstrapped for this observed $ATE_{test}$, this analyses indicated that $ATE_{test}$ for 2016 was statistically significantly lower than the target of 98%. Additionally, we found evidence that it is statistically unlikely that the parent population of Lewis River winter steelhead truly exhibited $ATE \geq ATE_{target}$ when the sample of fish that reached the Merwin Dam tailrace exhibited an $ATE_{test}$ of only 73%. Out of one million samples randomly drawn from an urn-style population modeled to truly exhibit 98% passage, zero (0) exhibited $ATE_{sim}$ as low as the value measured during 2016.

During the 2016 study year, winter steelhead appeared to locate and enter the trap at a substantially higher rate ($P_{EE}$ of 93%) than the rate at which they were capture (*i.e.*, $ATE_{test}$). This observation is reflected by a trap ineffectiveness ($T_i$) of 21% for 2016. While this number appears lower, and does suggest potential for improvement in trap efficiency, this is a 28% improvement (representing 8 percentage points) compared to $T_i$ for winter steelhead in 2015 (29%). Neither $ATE_{test}$ nor $P_{EE}$ for winter steelhead differed significantly between 2015 and 2016 study years[7].

Fish that were captured, tagged, and released earlier in the season had higher rates of recapture than fish that were captured, tagged, and released later in the season. Intriguingly, this was opposite the trend observed in 2015, when winter steelhead tagged earlier in the season exhibited a lower probability of being recaptured (see Figure 6, Stevens et al. 2015). In 2016, winter steelhead that were captured, tagged, and released after 11 April 2016 generally experienced less than 50% chance of successful recapture at the trap. This finding could be a result of at least one of the following:

1) environmental changes during the season, from conditions promoting passage to conditions impeding passage (*e.g.*, the increasing temperature differential between warm river water and cooler attractant water),
2) changes in dam or trap operations,
3) diminished fish energy reserves (*i.e.*, lipid stores), or
4) elevated stress in the fish due to their level of sexual maturity.

[7] As $T_i$ is a summary statistic derived from the same underlying measurements (*i.e.*, *T*, *C*, *M*; see **Table 4**), comparison of $T_i$ across years yields similar non-significant results.

Possibilities 3 and 4 could both cause individuals to be less "willing" to expend additional energy searching for the trap, and may increase odds of navigating back downstream and possibly to spawn.

This study is designed to make inference about the overall *ATE* of all immigrating adult winter steelhead, while a subset is tagged and their movements analyzed. It is, however, possible that the behaviors of the tagged fish in this study are different than other immigrating fish. Fish in this study were non-naïve fish to the trap because they had previously navigated to the Merwin tailrace, located the Merwin trap entrance, ascended the ladder and were successfully captured. After being collected for the first time, tagged, and trucked downstream, they were then released back into the river to repeat their efforts. From this study, three (3) findings emerged that suggest non-naïve fish may exhibit trap avoidance behaviors:

1) More than ¼ (*i.e.*, 26%) of fish that re-entered the Merwin tailrace swam back downstream below the Bridge before attempting upstream migration again, though these individuals could have crossed instead from the North Shore to the South Shore to gain more immediate access to the trap.
2) For some reason, there appears to be a preference for fish to approach the North Shore from the Bridge site,  but after arriving at the North Powerhouse Wall, fish then appear reluctant to cross the river in the area of spill and instead retreat downstream and try another route, *i.e.*, the south shore (Figure 11). It does not appear so much that fish are avoiding the trap, *per se*, as attempting to negotiate the rough water that may be present at this location in the tailrace.
3) The network analysis accomplished in this report suggests that there is not a clear pathway that fish are using to navigate to the trap. Specifically, more than half of the fish that were eventually trapped visited 100 or more sites prior to being trapped (Figure 13). The mean number of sites visited prior to being trapped was 213; with total of 18 sites in this study, this suggests that each fish was (a) detected at a site, (b) left for a second site, and (c) returned to the original site, on overage 12 times per receiver location.

Additionally, based on the network analysis figures (Figure 11, Figure 12, Figure 14) and median residence times (Figure 15, Figure 16, Figure 17), the majority of holding occurred at receivers north shore (North Shore) and immediately outside the trap enterance (Approach), whereas the majority of milling occurred at South Shore and South Powerhouse Wall receivers. The North Shore receiver had the longest total and median residence times of all sites, despite having a lower number of total visits, suggesting more holding and less milling at this location.

The probability of an individual fish progressing from the receivers Hopper↔Trap was 0.393 across its detection history, but the transitional probability across all fish path segments was much lower, at 0.093 (Table 6. Probabilities of transitioning further into the system for each site. $P_{single}$ is the probability of a fish transitioning forward to the next most upstream site(s) rather than falling back to the downstream sites. $P_{all}$ is the same probability, across all detections rather than across individual fish. *MI* is a milling index, calculated as the ratio $P_{single}:P_{all}$. Values that are positive suggest that fish tend to not move forward from that location. Site specific $P_{single}$ or $P_{all}$ <0.05 are shaded blue, and *MI* >0.000 are shaded green. Hopper site is bolded to note that this site was associated with the highest calculated *MI* (0.300), a value that was 35% greater than the next highest *MI*¸ which was associated with Pool 1-4 (0.221).). Overall, once a fish had been detected at Hopper receiver, it had a 39% chance of eventually being detected in the pre-sort pond (Trap), however, 91% of the time that a fish was detected at the Hopper receiver it was next detected moving back toward the entrance rather than being captured.

The network analysis visualization that compared successful versus unsuccessful fish (Figure 14) shows no apparent differences between the two groups. This finding suggests that: (1) there are some fish that make it as far as the hopper and are not caught; and (2) most fish that are not captured appear to mill in the tailrace rather than in the trap.

Based on the ARIS camera data analysis, there were nearly an equal number of entries and exits through the crowder while it was in the fishing position, indicating that the crowder does not adequately trap fish behind it. Fish are able to pass through the crowder in both directions in approximately equal capacity. A major avenue of fish capture appears to be fish moving up pool toward the crowder while it is in the closed position (flush against the hopper) and then becoming trapped behind it as it slides back down the wall and locks into its fishing position. Because fish are not adequately trapped behind the crowder, and large numbers of fish are caught at least temporarily behind the crowder during its reset cycle, we suggest that a more frequent crowder reset cycle will push more fish into the hopper and trap facility. Furthermore, there seems to be almost no adverse behavior associated with the crowder reset cycle as evidenced by the small number of fish leaving the pool during reset cycles, so it is unlikely that increasing the frequency of the reset cycle will result in lower numbers of fish being trapped.

The ARIS data were also used to aid in the interpretation of radio tag detections. When the ARIS was operational, 18 radio tagged fish were detected in fish crowder and conveyance system, indicating they had successfully navigated the entirety of the fish passage facility. As discussed above (*Objective 5*: Describe the movement and behavior of tagged fish that do not enter or which choose to leave the Merwin Dam tailrace and move back downstreamsection within *Results*, page 36), many of the fish that navigated to the trap subsequently moved back downstream. Consequently, only three of those 18 fish had RT detections from *both* the Pool 1-4 antennae (located next to the ARIS) *and* the Hopper antennae (located at the upstream end of Pool 1-4), constraining the amount of ARIS imagery that could be evaluated for cross comparison. Nevertheless, each of the three fish were identified in the ARIS imagery and provided sufficient data to make three conclusions:

1. Radio tagged fish moved back and forth from one end of Pool 1-4 to the other (in between the Pool 1-4 antennae and the hopper antennae) mainly when the crowder was in the closed position (flush to the hopper).

2. Radio tagged fish did exit through the crowder while it was in the fishing position.

3. If a radio tagged fish was behind the crowder when it went through a reset cycle, the fish was successfully captured.

The ARIS observation of radio tagged fish moving freely from one end of Pool 1-4 to the other while the crowder was in the closed position confirms our stand alone ARIS data which indicated that fish move up Pool 1-4 while the crowder is in the closed position and then become trapped behind the crowder as it moved back to the fishing position. ARIS observations of radio tagged fish exiting the crowder while it was in the fishing position also corroborate our record of 300 instances of similar behavior in the stand alone ARIS data. Linking the ARIS data with the radio tag data also led to one novel conclusion that our stand alone ARIS data could not verify: *Each of the three radio tagged fish were identified behind the crowder when it initiated its reset cycle*. Shortly afterwards, each fish was detected at the trap facility. This important result indicates that any fish that is behind the crowder when the crowder closes and pushes to the hopper, ends up at the trap facility. In other words, the crowder reset cycle seems to successfully trap any fish that are behind it. This result reinforces our recommendation from the stand alone ARIS data: increase the frequency of the crowder reset cycle.

A number of findings suggest that structural modifications within the trap may increase retention and increase *ATE:*

1) When at receiver Entrance, fish have approximately the same probability of being detected next at receiver Approach or at Pool 1-2, suggesting: a) the environmental or structural conditions are sub-optimal between the entrance and Pool 1-1; or that b) even if the conditions between trap entrance and Pool 1-1 are satisfactory, conditions at Approach or Pool 1-2 are better than at Pool 1-2. In either case, in approximately 50% of cases, fish appear to back away from the Entrance receiver and out of the trap[8].
2) The three (3) receivers with the greatest milling, as evidenced by the *MI* score, included: Hopper, Pool 1-2 and North Powerhouse Wall (Table 6). Of these three, receiver Hopper had the greatest *MI*, suggesting that operations could be improved at this location (*e.g.*, changes in the frequency of crowding, the way in which fish are crowded, the time of day the crowder is in operation, etc.) in order to trap fish more effectively and reduce the amount of total visits experienced.
3) Based on network analysis, the majority of trap-specific milling occurred between the receivers Hopper↔Pool 1-4 (Figure 11). This finding could be explained by: 1) detection zone overlap; 2) fish being "unwilling" to traverse the area between these sites; or 3) fish being unable to move forward to the hopper.

We operated three (3) simulation models to evaluate potential ways to increase *ATE* at the site. The first model showed minor effects on *ATE* values, but this may be due to the relatively high likelihood of fish exiting the tailrace from the North Shore but not from the South Shore. Thus, by increasing the transition rate between Bridge and South Shore, fewer fish exit the tailrace early from site North Shore (and no longer contribute low counts of visited sites). Model 2 suggested that installing a new trap (or a second entrance directing fish to the current trap) would decrease median sites visited, but not change the overall number of fish captured, which highlights the observation that fish that make it into the tailrace are likely to eventually be trapped. Adding a second trap simply allows them to be trapped earlier. The final model (Model 3) indicated that failing to enter the hopper results in extra transitions. The increase in trapped fish associated with this model represents those individuals that were previously unable to transition into the hopper, and ended up exiting the system through another point. This final

[8] *NB: If the signal strength requirement at the ENT receiver is omitted, then this ratio increases.*

model was the most encouraging of the three in terms of *ATE* increases, and in terms of likely costs to install.

In summary, the results from the simulations demonstrate that this is a system characterized by complex travel paths, with individual pathways only having minor influence on core passage metrics (*i.e.*, there do not appear to be any obvious passage bottlenecks). In our simulation, having the hopper operate more frequently (or otherwise retaining fish in the ladder once they have entered the trap) and thus more successfully has a larger impact than attempting to steer fish towards the south shore, or installing a second trap. Because this has such a strong effect on the system, and requires no additional construction projects, it stands out as a strong candidate for consideration when planning operational changes.

Finally, it is worth mentioning that 95 fish were detected at the receiver Entrance but then turned around to the tailrace receivers. Of these, nearly three-fourths (*i.e.*, 74% or 70 of 95 fish) were ultimately captured successfully. The approximately one-quarter (*i.e.*, 26% or 25 of 95 fish) of these fish that turned back downstream after being detected at the Entrance were never captured; most of these fish were last detected at the receiver Lewis River Hatchery (LRH) receiver.

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# APPENDIX A: SUPPLEMENTARY FIGURES AND TABLES

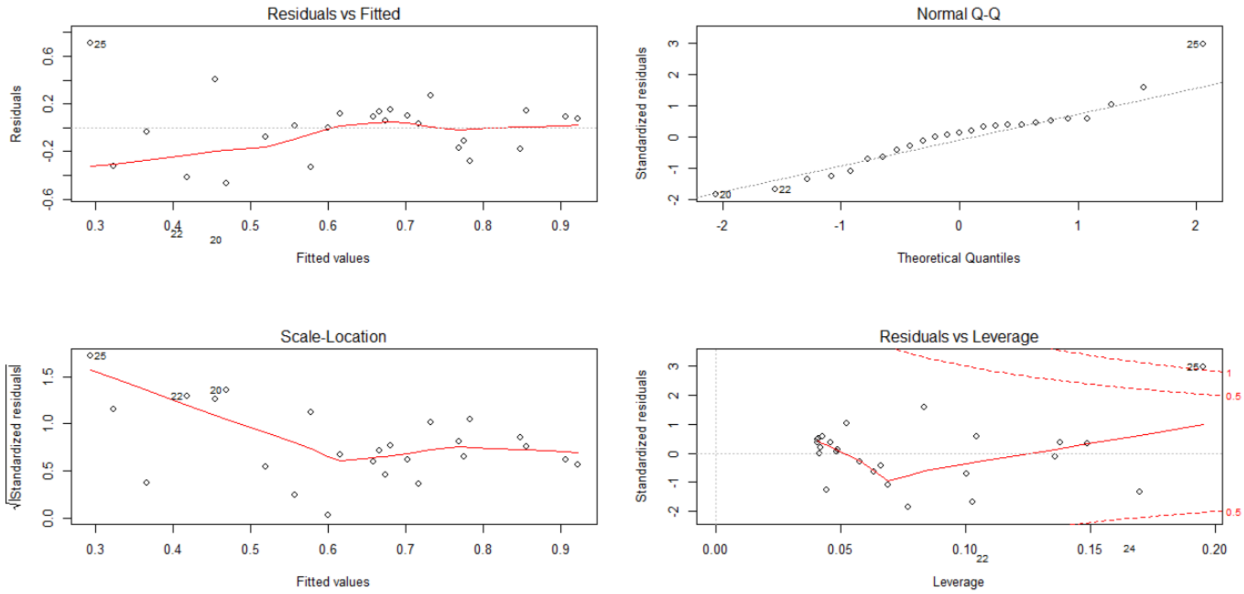


**Figure A-1.** Residual and normal probability plots to evaluate normality and homoscedastity of $ATE_{test}$ rates prior to operating an ANOVA.

## APPENDIX D

## UPPER BASIN SEED PLANT PROGRAM – 2016 SUMMARY

**Summary of the Adult Fish Seed Planting Program**
**Upstream of Swift Reservoir 2016**

Prepared by PacifiCorp
*February 24, 2017*

## Background

In 2015, PacifiCorp implemented and evaluated an extensive seed plant program (summarized in detail in Appendix F in the 2015 Annual Fish Passage Program Report). This program was developed based on results of earlier observations which indicated that adult fish released at the head of Swift Reservoir (i.e., Eagle Cliff Adult Release Site and Swift Forest Camp boat launch ) remained near the release site or traveled downstream and entered Swift Reservoir. As part of this effort, three additional releases sites were established in the upper watershed above Swift Reservoir. These sites included the Muddy River Bridge, the Clear Creek Bridge, and the upper Lewis River Bridge near Crab Creek. In 2015, approximately 47% of the winter steelhead and 7% of the coho salmon were release at one of these remote sites. Radio telemetry combined with an aerial survey and a fixed receiver at Eagle Cliff were used to evaluate fish behavior and movement in the upper basin and compared with earlier data (2014) when fish were only released at the head of Swift Reservoir. Results of this initial year of the 2015 evaluation indicated that by distributing a proportion of the adults further upstream did appear to improve fish distribution. This was particularly evident for winter steelhead. In an effort to promote a wider distribution and habitat utilization by transported fish, PacifiCorp continued seed planting efforts in 2016. The following sections provide a summary of observations made for both winter steelhead and coho salmon during the 2016 effort.

## Winter Steelhead

Of the 772 winter steelhead released upstream of Swift Reservoir in 2016, about 47 percent (n = 360) were released at the three remote sites in the upper basin (Table 1). These fish were released approximately evenly among sites with 127 adults released at the Muddy River site, 127 at the Clear Creek site, and 106 released in the upper Lewis River.

A total of 93 winter steelhead with radio tags were released upstream of Swift Dam in 2016; releases occurred from mid-March through mid-May with release rates peaking during the third week of April. A portion of these radio tagged steelhead were released at seed plant locations on Muddy River (n=16), Clear Creek (n=14), and the Upper Lewis River near Crab Creek (n=4), the remainder were released at the Swift Forest Camp site (n=59). During 2016 radio tags were

**Table 1. Distribution between release sites of radio tagged and untagged winter steelhead during 2014 and 2016.**

| Winter Steelhead 2016 | Eagle Cliff | Upper Watershed | | | | Combined Total |
|---|---|---|---|---|---|---|
| | | Muddy River Bridge | Clear Creek Bridge | Upper Lewis (Crab Creek) | Total | |
| Untagged | 353 | 111 | 113 | 102 | 360 | 679 |
| Radio Tagged | 59 | 16 | 14 | 4 | 34 | 93 |
| Total | 412 | 127 | 127 | 106 | 456 | 772 |

In 2016, radio tags were detected throughout the Muddy River, Clear Creek, and Lewis River while Pine and Drift Creeks saw a decline in usage when compared to pre-seeding conditions (2014) (Figures 1 and 2). These results are consistent with previous finding that indicated that seed planting efforts help distribute winter steelhead throughout the upper basin during reintroduction (summarized in detail in Appendix F in the 2015 Annual Fish Passage Program Report).

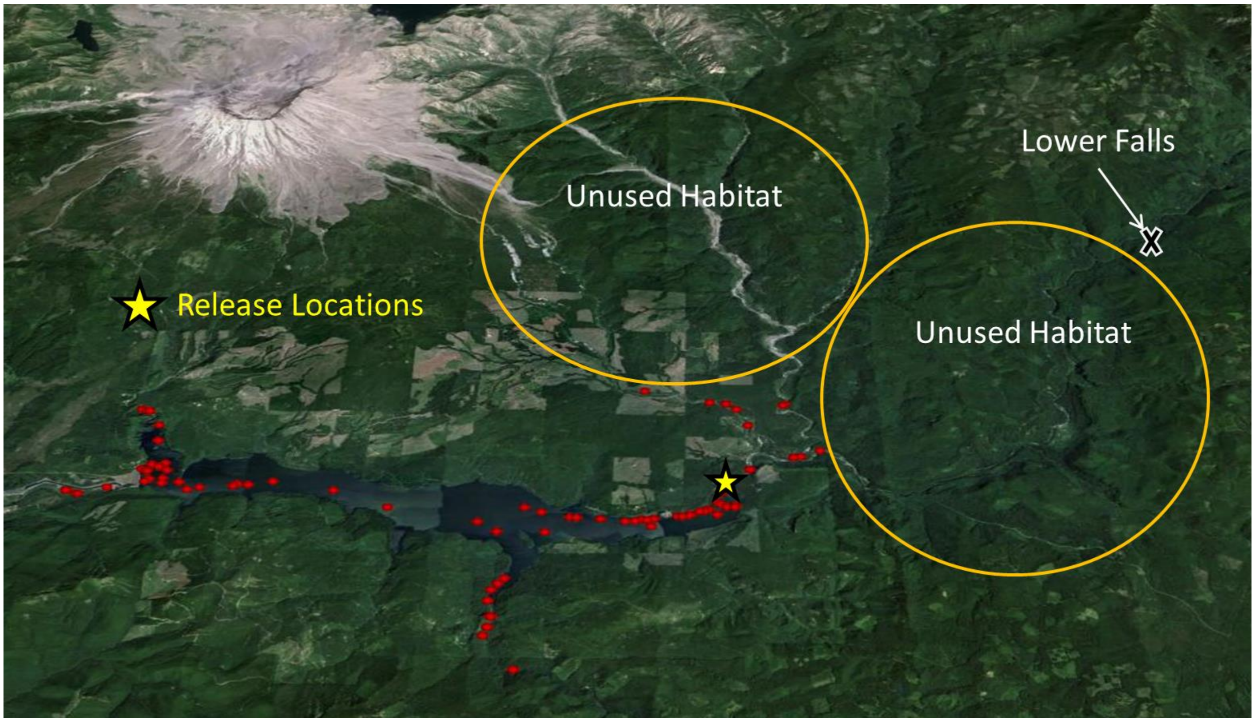


**Figure 1. Steelhead detections during the spring of 2014 when all fish (including radio tagged) were released at either Swift Forest Camp or Eagle Cliff sites. Data combines all four flights. (Details of this evaluation are summarized in Appendix F in the 2015 Annual Fish Passage Program Report).**

**Figure 2. Steelhead detections during the April 28, 2016 survey flight.**

## Coho Salmon

The coho seed planting activities during 2015 and the telemetry findings associated with it showed that seed planting coho in remote sites in the upper basin helped spatially widen the coho spawning distributions versus seasons when no seed planting occurred (summarized in detail in Appendix F in the 2015 Annual Fish Passage Program Report). Because of this, PacifiCorp planned to perform similar seed planting efforts for coho during 2016. It was originally planned to seed plant approximately 10% of the total amount of Type-S and Type-N coho transported above Swift Dam. The original intent of seed planting coho, particularly for Type-S coho, was to help attract fish upstream during low flow periods typically observed during the first portion of the Type-S run. During the early portions of the Type-S run there were historically low water conditions and it was observed that pre-spawn mortality was occurring near the release locations, because of this seed planting activities were suspended until water levels rose. These low flow conditions were eventually followed by abnormally high water conditions during most of the remaining type-S run. About 2% of the Type-S coho (83 of 4,111 fish) transported above Swift Dam were seed planted. However, once the high flow events had occurred, observations made by redd surveying crews showed that coho appeared to be distributing widely throughout the upper watershed in 2016 (Appendix D – Spawn Timing, Distribution, and Abundance of Transported Fishes). More favorable seed planting conditions occurred during the type-N coho run, allowing for increased seed planting efforts. Approximately 14% of the type-N run (446 of 3,235 fish) transported above Swift Dam were seed planted. In total 7% of the coho (529 of 7,346 fish) transported above Swift Dam were seed planted in 2016 (Table 2).

**Table 2. Distribution of release sites for both type-S and type-N coho are shown. Upper watershed sites are considered seed plant locations.**

| | Eagle Cliff | Upper Watershed | | | | | Combined Total |
|---|---|---|---|---|---|---|---|
| | | Muddy River Bridge | Clear Creek Bridge | Upper Lewis (Crab Creek) | Total | Percentage | |
| **Coho Type-S** | 4,028 | 45 | 38 | 0 | 83 | 2% | 4,111 |
| **Coho Type-N** | 2,789 | 170 | 276 | 0 | 446 | 14% | 3,235 |
| **Total** | *6,817* | *215* | *314* | *0* | *529* | *7%* | *7,346* |

## APPENDIX E

## SPAWN TIMING, DISTRIBUTION, AND ABUNDANCE OF TRANSPORTED FISHES – 2016 REPORT

**Meridian to provide results**