Lewis River Fish Passage Program
2018 Annual Report (Final)

Monitoring and Evalaution (M&E) Plan Metrics

FERC Project Nos. 935, 2071, 2111 and 2213

Woodland Release Ponds - Photo by Greg Glaze

PacifiCorp
&
Public Utility District No.1 of Cowlitz County

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Appendix C Merwin Adult Trap Efficiency Evaluation (Coho Salmon) – 2018 Report

Appendix D Spawn Timing, Distribution and Abundance of Transported Fishes – 2018 Report

ACRONYMS AND ABBREVIATIONS

ACC	Aquatics Coordinating Committee
ADCP	Acoustic Doppler Current Profiler
ATE	Adult Trap Efficiency
AWS	Auxiliary Water Supply
BKD	Bacterial Kidney Disease
CE	Collection Efficiency
CFS	Cubic Feet Per Second
CWT	Coded Wire Tag
EA	Electro-Anesthesia
FCE	Fish Collection Efficiency
FL	Fork Length
FPS	Feet Per Second
FSC	Fish Collection Facility
H&S	Hatchery and Supplemental Plan or Subgroup
HR	Hatchery returns
LWS	Ladder Water Supply
mm	millimeter
NTS	Net Transition Structure
ODS	Overall Downstream Survival
PIT	Passive Integrated Transponder tag
RMIS	Regional Mark Information System
ROV	Remotely Operated Vehicle
SAF	Sorting Area Flow Pumps
UPS	Upstream Passage Survival
ZOI	Zone of Influence

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 2018. The M&E Plan was developed as part of the Settlement Agreement to evaluate performance measures outlined in the new FERC Licenses. These Licenses were issued to PacifiCorp and Cowlitz PUD for operation of the North Fork Lewis Hydroelectric Projects on June 26, 2008. This report summarizes both upstream and downstream fish passage and collection metrics as well as provides an overview of environmental conditions and key procedural changes that occurred in 2018. The following is a brief summary of relevant performance metrics documented in this report:

Description	M&E Obj.	Performance Goal	2018 Data	Summary
Number of Juveniles Passing Eagle Cliff During Screw Trap Operations	Obj. 7 Task 7.1	Monitoring	50.839 coho 3,195 steelhead 2,676 Chinook 1,365 cutthroat	Estimates of the total number of juvenile coho, Chinook, steelhead, and cutthroat were made over a 16-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	150,266 coho 17,718 steelhead 19,290 Chinook 4,713cutthroat	Estimates of the total number of juvenile coho, steelhead, and cutthroat that entered Swift Reservoir during 2018.
Number of Fish Collected at the Swift Floating Surface Collector (FSC)	Obj. 6	Monitoring	41,999 coho 7,900 steelhead 4,750 Chinook 876 cutthroat	A total 57,825 salmonids were captured by the FSC in 2018. Of these fish, 55,336 were transported and released downstream of Merwin Dam.
Juvenile Migration Timing	Obj. 8	Monitoring	Various	Overall, the run timing in 2018 followed a normal frequency distribution, with peak migration occurring in mid-May. Over 85% of all fish collected at the FSC in 2018 were collected between March 1 and June 30.
FSC Collection Efficiency (CE)	Obj. 2	Juvenile Collection Efficiency > 95%	Coho 39.5% Chinook 23.7% Steelhead 48.9%	In 2018, CE was evaluated using PIT tag mark-recapture, therefore estimates were conservative compared to previous years. Estimates of efficiency among all species were the highest observed since the commissioning of the FSC in 2012, however the 95% collection efficiency standard was not met in 2018.
Swift FSC Injury	Obj. 5	Smolts and Fry < 2%	Fry (0.0%) Smolt (0.09%)	Annual injury rates for all juvenile salmonid species met the required performance standard of 2.0%.

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[1] The methods used in this report follow the revised methods for the M&E Plan dated 2016.

Description	M&E Obj.	Performance Goal	2018 Estimate	Summary
Swift FSC Survival	Obj 4.	Fry > 98.0% Smolt > 99.5%	Fry (100.0%) Smolt (98.7%)	The survival rate for salmonid fry (100%) met the 98% performance standard in 2018. However, the combined survival for parr and smolts (98.7%) did not meet the performance standards of 99.5%. Periods of heavy debris loading largely contributed to this metric not being met.
Overall Downstream Survival (ODS)	Obj. 1	> 80%	Coho 27% Chinook 23.3% Steelhead 43.5% Cutthroat 19%	During 2018, 1,073 coho, 439 steelhead, 96 cutthroat, and 408 Chinook were tagged and released for the ODS study. Of these fish, 290 coho, 97 Chinook, 191 steelhead, and 18 cutthroat were recaptured at the FSC and passed downstream. In 2018, all species exhibited the highest ODS observed since commissioning of the FSC.
Number of Adult Fish Collected at the Merwin Fish Collection Facility	Obj. 11	Monitoring	Various	A total 15,328 fish were captured at the Merwin Trap in 2018. A total of 1,225 blank wire tag winter steelhead, 700 spring Chinook, 2,148 early coho, 4,912 late coho, and 77 cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program.
Adult Upstream Passage Survival (UPS)	Obj. 9	99.50%	Coho (S) 99.8% Coho (N) 99.8% Chinook 98.4% Steelhead 100% Cutthroat 100%	All cutthroat and winter steelhead survived the trapping and transport processes resulting in a UPS of 100 percent.. Four early (S) coho mortalities were observed, resulting in a 99.8 percent UPS. Nine late (N) coho mortalities were observed, resulting in a UPS of 99.8 percent. Eleven spring Chinook were recorded as mortalities, ten of which occurred at the Merwin Trap, which resulted in a UPS of 98.4 percent in 2018.
Adult Trap Efficiency (ATE)	Obj. 10	> 98%	Coho 68% Chinook NA Steelhead 93%	A fourth year of evaluation was completed in 2018 for blank wire tag (BWT) winter steelhead, as well as a third year for coho salmon. The estimated collection efficiency for BWT winter steelhead and coho was 93 percent and 68 percent, respectively.

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 in coordination with the other projects. Combined, the Lewis River Projects have a generation capacity of 606 megawatts.

On June 26, 2008, PacifiCorp and Cowlitz PUD, FERC issued Orders 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 a carefully devised plan to protect the Endangered Species Act (ESA) listed species and to verify the effectiveness of passage facilities as the reintroduction program takes 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 2019[2].

The Lewis River Aquatic Monitoring and Evaluation (M&E) Plan (PacifiCorp and Cowlitz PUD 2016) 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 original M&E Plan were completed in early 2017 and this report follows the updated methods. The purpose of this report is to document results of the

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[2] A decision on whether subsequent phases are implemented was oringinally scheduled for Feburary 24, 2017. However,further time was requested by the Agencies before reaching a decision. Under the current schedule, it is anticipated that a decision will be reach by March 1, 2019.

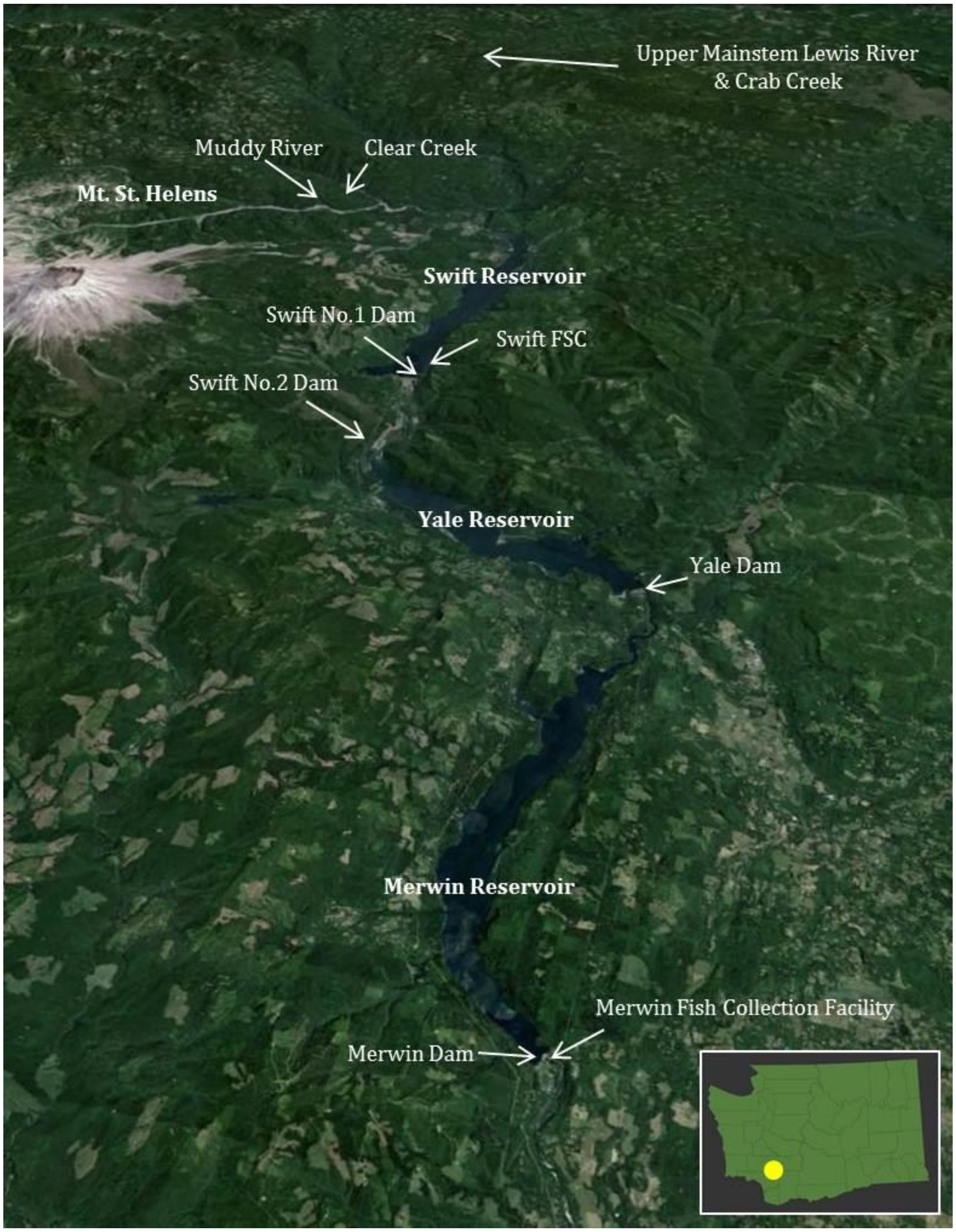

Figure 1.0-1. An overview of key features of the North Fork Lewis River Hydroelectric Project area located in southwest Washington.

field assessments associated with implementation of the fish passage program in the existing M&E Plan during 2018.

Some noteworthy environmental conditions and procedural changes occurred or were continued to be implemented in 2018. These are summarized below:

- *Minimum Flow Requirement Below Merwin Dam:* During calendar year 2018, flows below the Merwin Project were maintained at or above minimum flow levels stipulated in the June 26, 2008

FERC licenses. On average, flows below Merwin Dam were lower than the 10-year average, particularly from April through November, due to lower than average snowpack (Figure 1.0-2).

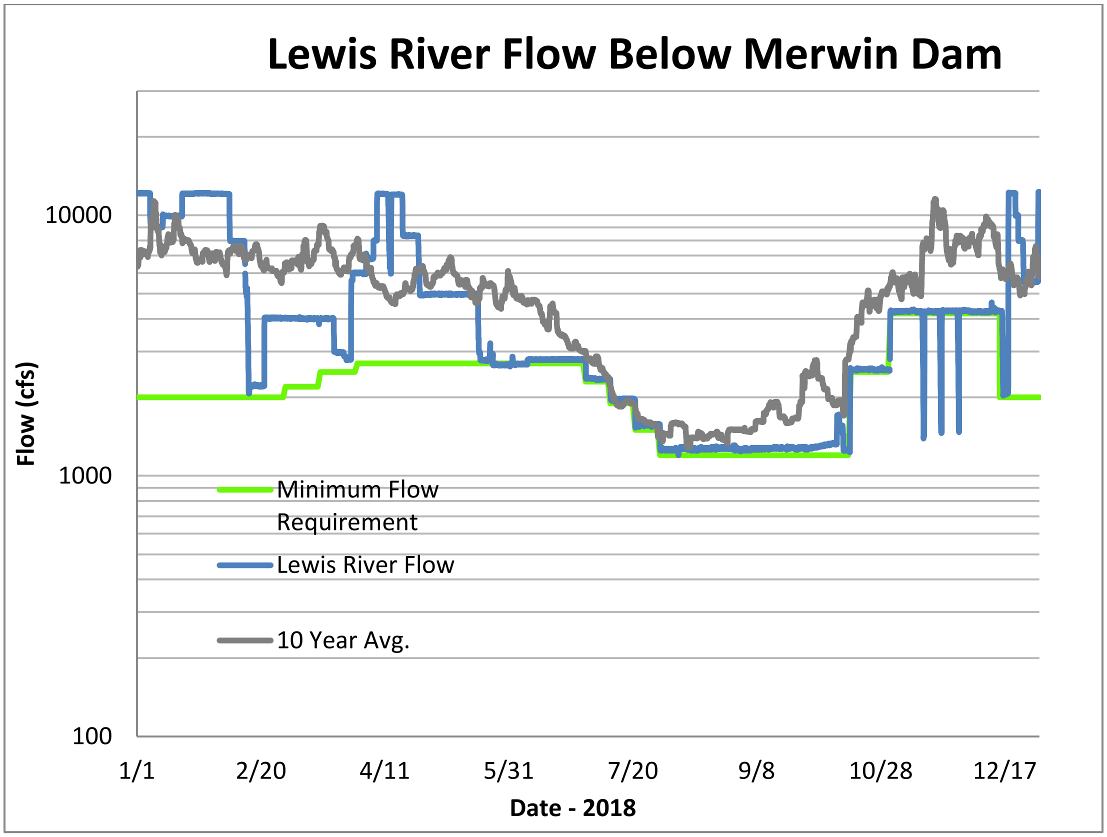

Figure 1.0-2. Lewis River flow below Merwin Dam as recorded by USGS gage (14220500 Ariel WA). Minimum flow requirements for 2018 requirements are also shown. The sharp 'dips' in flow during November are scheduled drawdowns associated with WDFW fall Chinook surveys.

- *FSC Summer Outage and Maintenance Period:* In March 2015, the ACC accepted operational changes that allowed the FSC to be turned off during warm reservoir conditions that occur in the summer (Lewis River Fish Passage Program Annual Report 2015 – PacifiCorp 2015). This was done because data indicated that once reservoir temperatures reach approximately 18 ^{o}C, catch rates of fish declined precipitously. Those fish that were collected also experienced high levels of mortality. Annual maintenance activities are to be performed during this summer outage period. It was also decided that while the FSC was off line, operation of the Merwin Trap would be changed from a seven day per week schedule to a five day per week schedule (Lewis River Fish Passage Program Annual Report 2015). This temporary schedule allows the fish crowder and lift assembly to remain operational seven days per week; however, daily sorting of fish only occurs Monday through Friday. These operational changes were also followed in 2018.

- *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 2018. 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 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 adult coho.

- *Releases of Acclimation Fish Changed From Upstream Releases to Downstream Releases:* On May 31, 2018, the Hatchery and Supplementation (H&S) subgroup met to discuss the Spring Chinook Acclimation Program above Swift Dam. The original program called for 100,000 hatchery reared juvenile spring Chinook salmon to be released at various acclimation sites upstream of Swift Dam. These fish would then beheld for up to a month before being released and allowed to volitionally migrate downstream. The primary purpose of the program was to promote the distribution of returning adults spawners throughout the available upper basin spawning habitat. As naïve hatchery spring Chinook adults transported above Swift Dam in 2017 and 2018 spawned widely across the available habitat (throughout the upper Lewis River, Muddy River watershed, and Swift Reservoir tributaries), it was thought that the acclimation of juvenile spring Chinook may not be necessary, and that releasing an additional 100,000 fish in the lower river to return as adults and be taken upstream would be a better strategy to meet recovery goals. PacifiCorp developed a release strategy memo that outlined three potential options for releasing the 100,000 spring Chinook smolt formally allocated to the upper basin acclimation ponds over the next five years (2019 – 2024; a copy of the memo can be found in Appendix A). The H&S subgroup recommended that begining in 2019, all juveile spring Chinook formally allocated to the upper basin release ponds will be fully intregated into the existing Lewis River hatchery spring Chinook program; thereby increasing the overall annual program goal from 1.25 to 1.35 million per year. By increasing hatchery production in the lower river and ultimately returning adults, more adults will be availalbe to be taken upstream as part of the reintroduction efforts. This increase in fish numbers would also help to increase sample sizes for the spring Chinook as part of the ongoing H&S release stragety evaluation. This action was discussed and approved at the June 14, 2018 Lewis River Aquatic Corrdination (ACC) Meeting.

  The 2018 acclimation fish were not released in the upper basin, but rather released below Merwin Dam. Because of their smaller size, these fish could not be integrated into the new release stragety and ongoing evaluation. Consquently, all smolt retained their adipose fins but were differentially marked with a ventral fin clip to identify this group from true natural origin (NOR) fish upon their return as adults. In November 2018, three (3) separate release groups were released into the Woodland Release Ponds (Table 1.0-1). This release timing was selected based on the natural spring Chinook out-migration patterns observed at the Swift Floating Surface Collector in previous years. After each group was released, they were allowed approximately 6 days to volitionally migrate into the North Fork Lewis River. On the 7th day, the fish that had not migrated out of the Woodland Release Ponds were forced out via manual crowding nets.

Table 1.0-1: Summary of 2018 acclimation fish released into the Woodland Release Ponds and subsquentlly into the Lower North Fork Lewis River downstream of Merwin Dam.

Release Date	Number	Size
11/1/18	29,700	14.0 F/LB
11/15/18	30,680	13.9 F/LB
11/27/18	30,970	12.1 F/LB
Total	**91,350**	

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 five primary structures:

- Fish Collection Barge
- Truck Access Trestle
- Mooring Tower
- Barrier and Lead (Guide) Nets
- 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 and to capture them. 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[3]. 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).

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[3] Following transport downstream, smolts are released into ponds located near Woodland, WA (i.e., Woodland Release Ponds). Fish are held in these ponds for 24 hours before being allowed to volitionally enter the river.

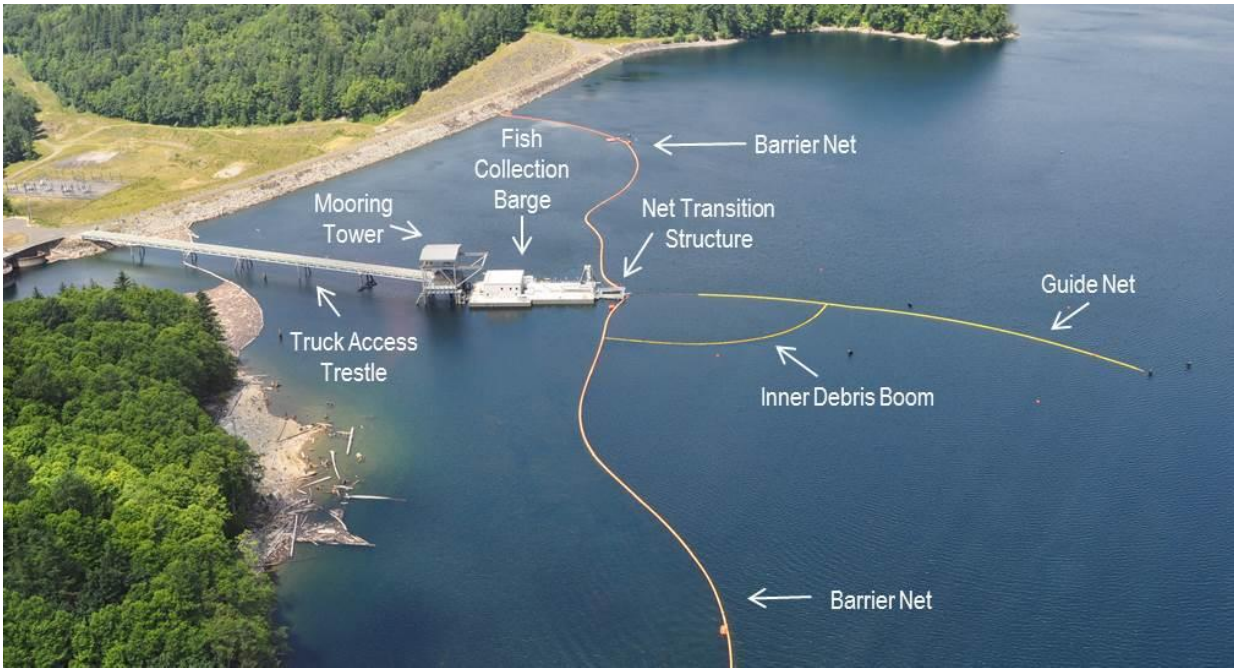

Figure 2.1-1. Aerial photo of the Swift Floating Surface Collector.

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[4].

The portion of the exclusion net 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 is solid material running 0-15 feet below the surface. The middle net section (15-30 feet) is 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, the exclusion net sustained damage during severe weather conditions. The extent of this damage was evaluated with a number of dive and remotely operated vehicle (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 lead net was installed at the entrance of the FSC. The purpose of the lead net is to orient out-migrants towards the entrance of the collector and improve collection efficiency. The total length of the lead 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 a 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

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

extends approximately 30 feet inside from the entrance of the existing NTS to prevent fish from easily swimming back out the opposite side of the FSC.

The FSC operated 24-hours a day through 2018 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 2018.

Date	Reason For Outage
03/15/18-03/16/18	Primary Screen back-flow flap replacement
07/17/18-10/16/18	Summer Maintenance Period
11/12/18	Power Outage

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 was 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

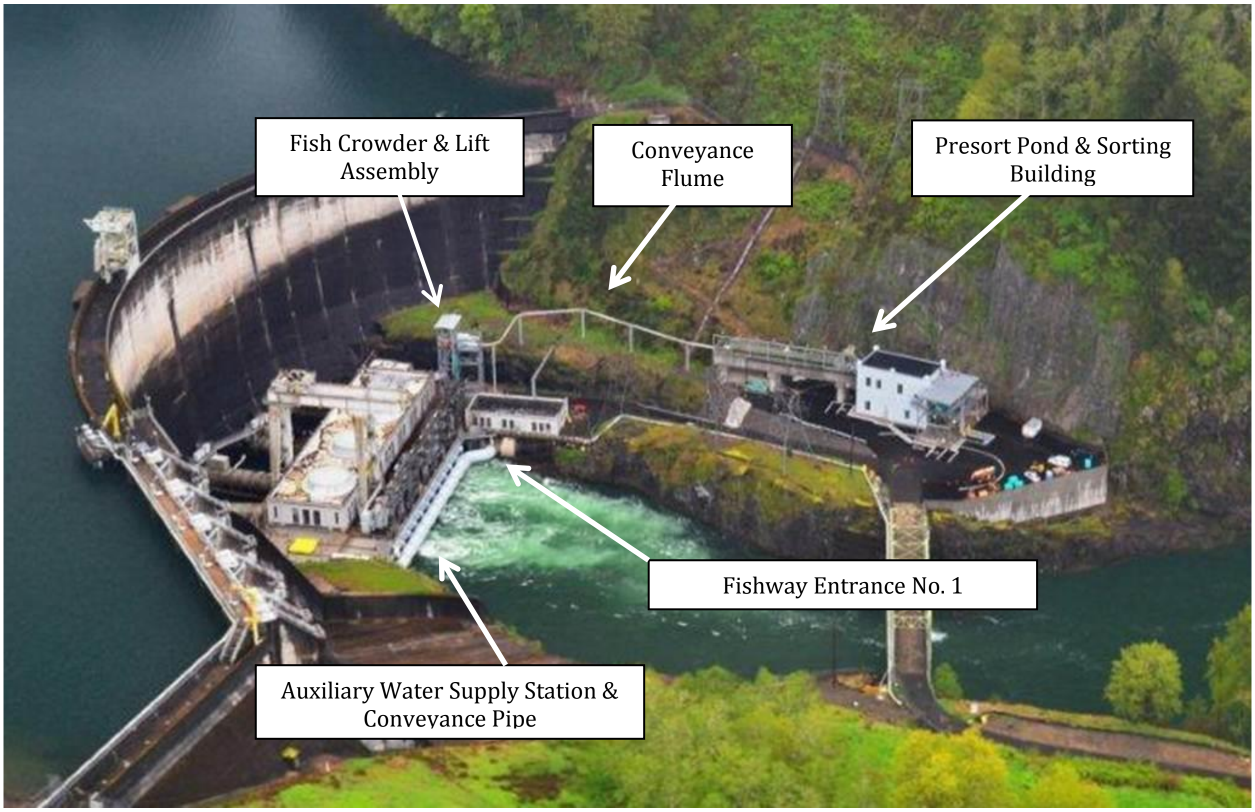


Figure 2.2-1. Merwin Sorting Facility.

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 used (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 to increase 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 elevation. 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 vertical fyke was installed on the upstream side of the Pool 1-2 weir in November 2016. The "V" style fyke was constructed with one inch stainless steel bars with a spacing of two inches on center and has an exit slot width of six 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 performed manually on the sorting table 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-anesthesia (EA) system temporarily anesthetizes 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 operated 24-hours a day through 2018 except during periods when it was necessary to shut the facility down due to facility modifications, scheduled maintenance or repairs (Table 2.2-1).

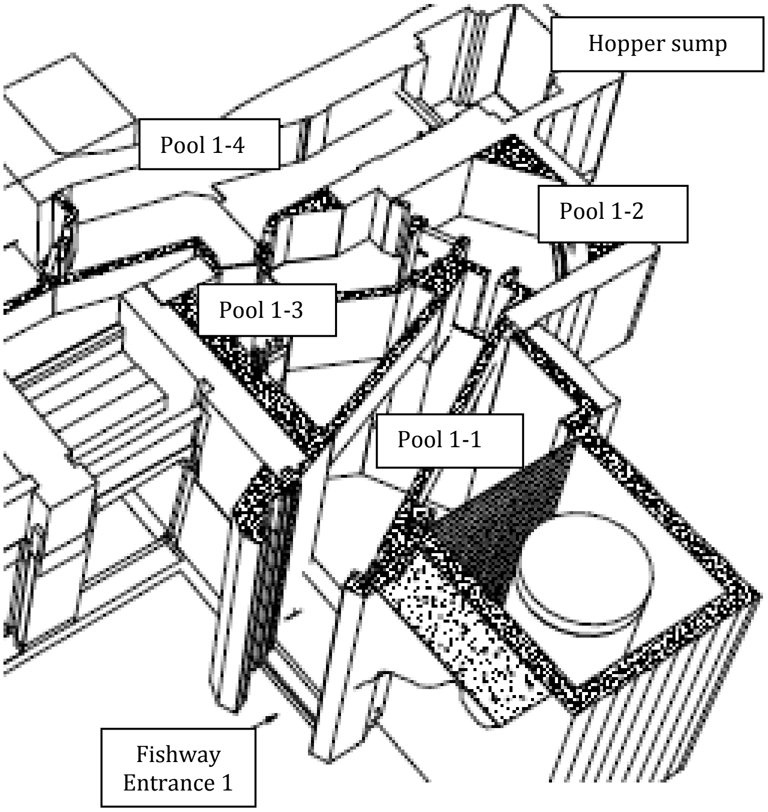


Figure 2.2-2. Merwin Sorting Facility ladder entrance and pool configuration.

Table 2.2-1. List of scheduled outages at the Merwin Fish Sorting Facility in 2018. The fish ladder and fyke remained operational - only the fish lift and crowder assembly was not operated.

Outage Duration	Purpose for Outage
1/1/18-1/2/18	Mechanical issues
1/9/18	Part replacement on fish crowder
1/11/18-1/24/18	Part replacement on fish crowder
2/16/18	Faulty hoist block on hopper
5/5/18-5/6/18	Faulty AWS pumps
5/12/18-5/13/18	Faulty hoist block on hopper
5/18/18-5/20/18	Fish hopper cable replacement
8/2/18-8/8/18	Schedule maintenance
9/16/18-9/17/18	Faulted limit switch
11/26/18-11/28/18	Fish hopper block replacement
12/7/18-12/17/18	Fish hopper cable replacement

2.3 Woodland Release Ponds

Construction of the Woodland Release Pond Facility was completed on December 15, 2017. The facility's purpose is to allow for stress reduction and determination of transport survival for out-migrants transported downstream from the Swift Reservior FSC before volitional release into the lower Lewis River at approximately rivermile 8.5.

The Woodland Release Pond Facility comprises of four cast in place concrete smolt release ponds (Figure 2.3-1). Each pond has a volume of 1,760 cubic feet and a 475 gallon per minute continuous flow rate. Water is supplied by a series of alternating pumps that lift water from the main river channel and into the ponds. Once transferred from the transport truck to the ponds, fish are held for 24-hours and any mortalities enumberated. Following the holding period, an isolation gate is lifted and out-migrants are allowed to exit the ponds volitionally. Any remaining fish are forced from the ponds. Out-migrants exit through a fish transfer flume and outfall into the lower Lewis River.

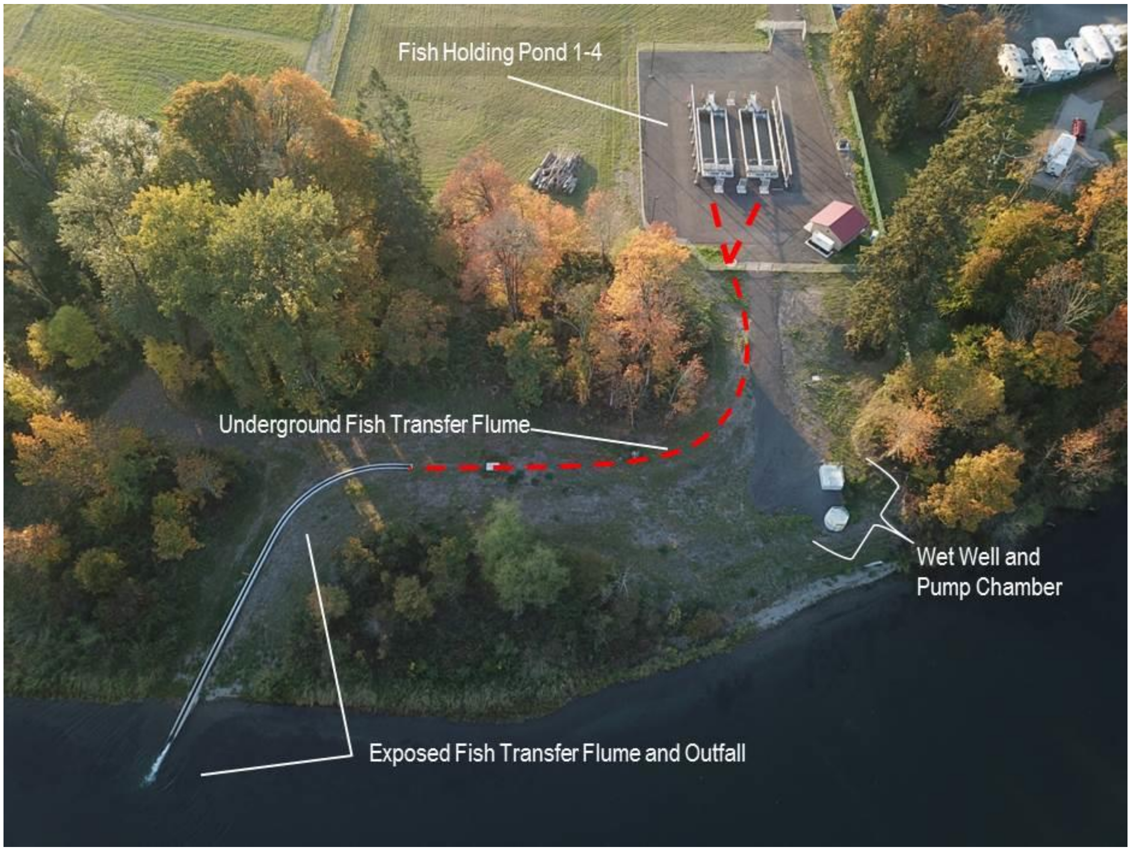


Figure 2.3-1. Aerial photo of the Woodland Release Ponds and associated infrastructure near Woodland, WA.

3.0 DOWNSTREAM COLLECTION AND PASSAGE METRICS

3.1 Number of Juveniles Entering Swift Reservoir

3.1.1 Overview

Developing an annual estimate of the total number of juveniles entering Swift Reservoir is required under Section 9.2.1 of the Settlement and is identified as Objective 7 of the M&E Plan. Historically, numbers 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 number of anadromous fishes likely migrate into Swift Reservoir when the Eagle Cliff screw trap is not in operation (Fall – late Winter). Additionally, these historical estimates do not include fish that enter Swift Reservoir from reservoir tributaries (e.g., Drift Creek).

The revised M&E Plan addressed this issue by dividing 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 serve 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 Reservoir 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:

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

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:

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

- 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:

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

Entire monitoring period variance:

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

95% Confidence Interval:

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

- 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:

Using 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 (Overall Downstream Survival (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; Caldwell et.al 2017; Anchor QEA 2018). Comparing the size class of fish captured at the screw trap to those at the FSC, in addition to assessing 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 2018, yearly parsing between fish brood years was not done as more long-term data is needed. Instead, fish captured at the FSC that were 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 were 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 was 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 13 March to 30 June, 2018, and checked the trap on a daily basis. The trap was turned off (cone raised) due to heavy debris loads from 4 Apri to 15 April, 2018; 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 300 mm in length (Figure 3.1-1). Juvenile coho were generally smaller, with only about 15% of the captured individuals being larger than 100 mm. Much of the spring Chinook catch was smaller as well, with only about 10% being larger than 80 mm. In contrast, more than 50% of the cutthroat and rainbow (steelhead) trout collected were greater than 100 mm in length.

A total of 1,404 coho, 36 Chinook, 194 rainbow/steelhead, and 83 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. Sufficient data was collected to produce species/origin-specific trap efficiencies for both coho and hatchery Chinook (Table 3.1-1). Due to low capture rates, an adjusted season average trap efficiency was set for naturally produced Chinook, steelhead and cutthroat (Table 3.1-2). (It is important to note that all spring Chinook captured in the screw trap in 2018 were of natural origin as no hatchery-raised spring Chinook acclimation juveniles were planted above Swift in 2018.)

Capture timing of juvenile salmonids tended to peak during the beginning of April (Figure 3.1-2). Differing from this were steelhead that peaked at the end of April. 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 for calculating total outmigration described by Volkhardt et al. (2007) for a single partial capture trap was used to make a secondary estimate (Table 3.1-3). In total 50,839 coho, 2,676 naturally produced Chinook, 3,195 steelhead, and 1,365 cutthroat were estimated to pass the trap during trapping operations (Table 3.1-3). 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 out-migration abundance.

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

Species	Total Hatchery Produced ≥60 mm FL	Total Naturally Produced <60 mm FL	Total Naturally Produced ≥60 mm FL	Total Marked & Released Upstream ≥60 mm FL	Total Recaptured	Total Season Trap Efficiency
Coho	0	1,693	1,412	1,404	69	0.049
Chinook[a]	0 juvenile	129	36	36	6	0.167
Rainbow/Steelhead[b]	0 juvenile	3	196	194	6	0.031
Cutthroat	NA	1	84[c]	83	5	0.060
Bull Trout	NA	7	13	0	1	NA
All Salmonids Combined			1,741	1,717	86[d]	0.050

Species	Total
Dace	3
Lamprey	3
Mountain Whitefish	1
Sculpin	43
Sucker	43
Three-spined Stickleback	19

[a] In addition, 1 adult wild Chinook and 2 mini-jacks were captured in the screw trap.

[b] In addition, 1 adult hatchery rainbow trout, 2 adult hatchery steelhead, and 8 adult wild steelhead were captured in the screw trap.

[c] A wild cutthroat trout (250 mm FL) with a PIT tag was captured in the screw trap, which was not originally captured and PIT tagged at the screw trap during 2018. This cutthroat was released downstream.

[d] Total recaptures do not include the single recaptured bull trout as no bull trout were released upstream of the trap for efficiency tests.

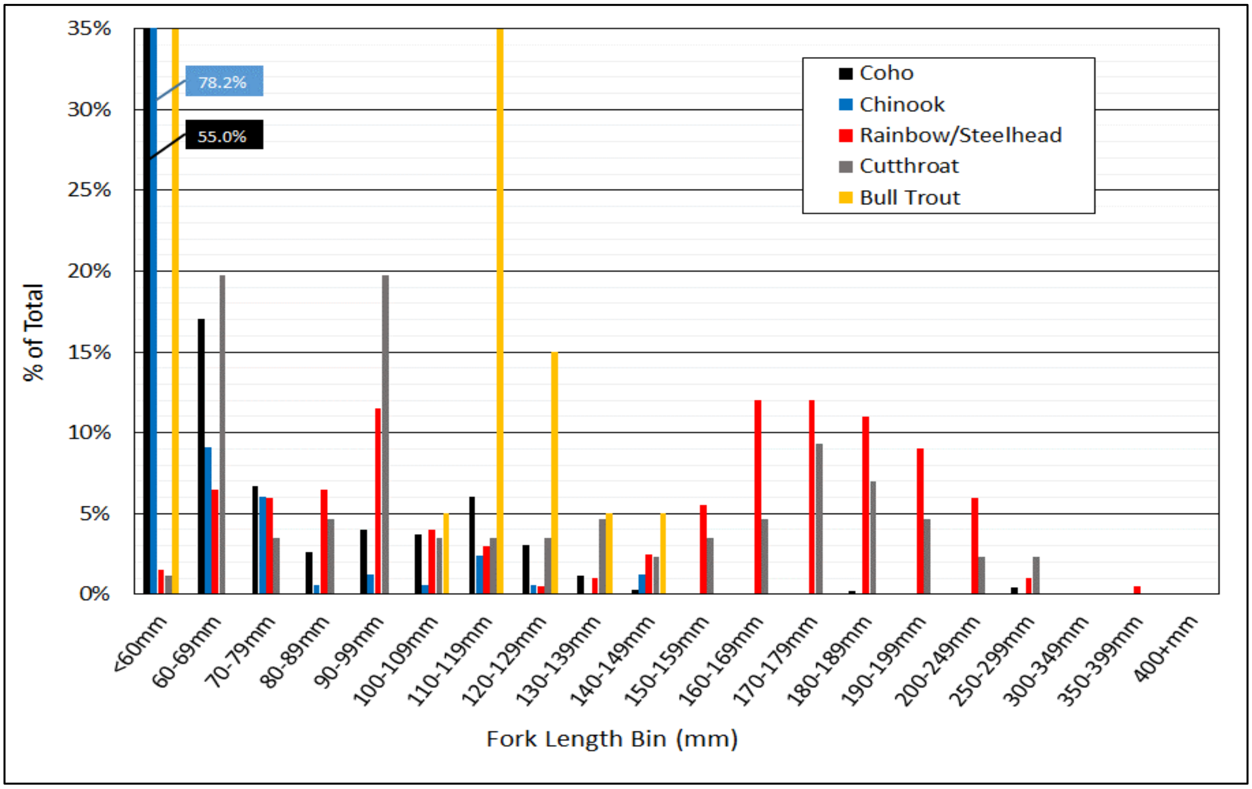


Figure 3.1-1. Length frequency distribution of juvenile coho, rainbow/steelhead (not including hatchery planted rainbows), and cutthroat trout.

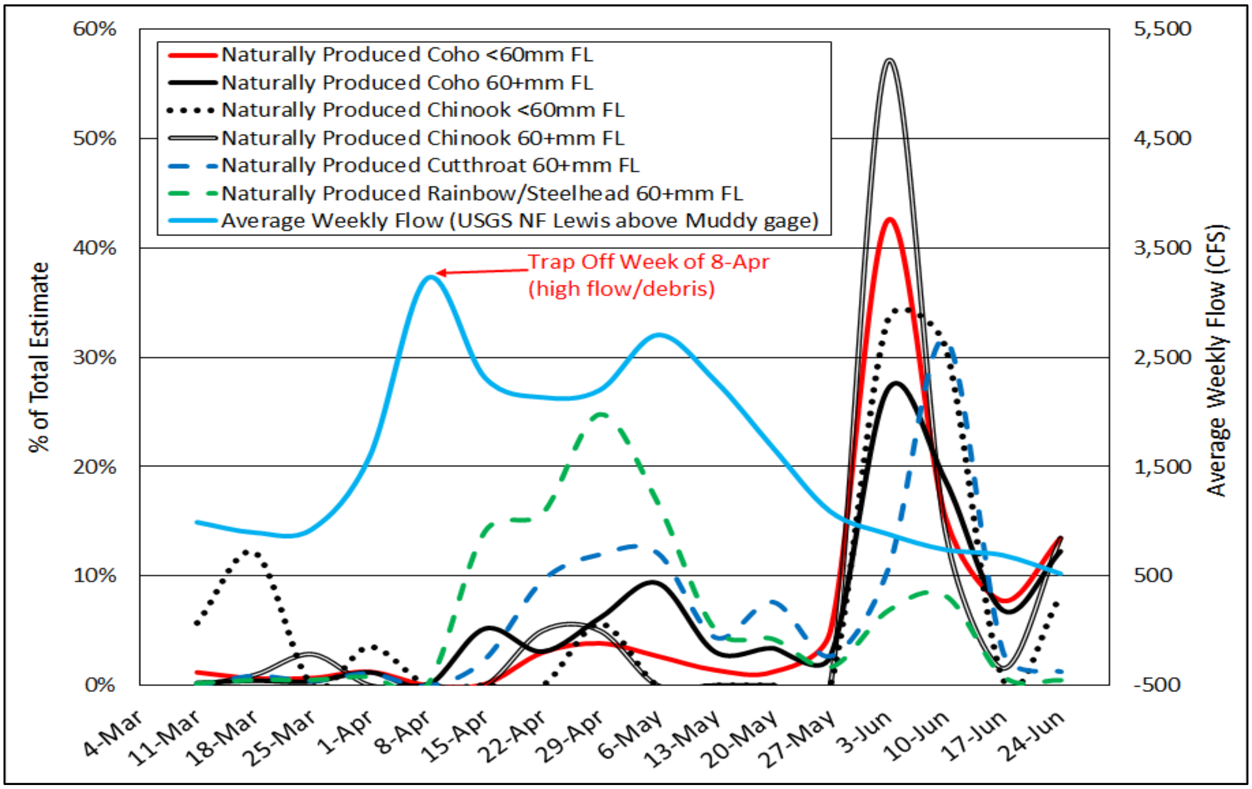


Figure 3.1-2. Species migration timing based on total weekly estimates (adipose fin intact).

Table 3.1-2. Summary of mark-recapture tests of trap efficiency for the Eagle Cliff screw trap.

Week (first day)	Total Caught ≥60 mm FL	Total Marked & Released Upstream ≥60 mm FL	Total Recaptured	Trap Efficiency	Average Weekly Flow (cfs)[a]	Adjusted Efficiency Based on Flow
11-Mar	10	10	1	0.100	992	0.118[b]
18-Mar	22	21	3	0.143	897	0.118[b]
25-Mar	21	20	2	0.100	929	0.118[b]
1-Apr	21	21	1	0.048	1,596	0.048[c]
8-Apr	trap not operated due to damage/debris			NA	3,223	NA
15-Apr	56	54	2	0.037	2,314	0.022[d]
22-Apr	48	45		0.000	2,134	0.022[d]
29-Apr	81	80	2	0.025	2,201	0.022[d]
6-May	186	181	8	0.044	2,704	0.044[c]
13-May	98	96	7	0.073	2,287	0.073[c]
20-May	105	100	7	0.070	1,677	0.070[c]
27-May	77	76	6	0.079	1,091	0.079[c]
3-Jun	342	341	12	0.035	884	0.035[c]
10-Jun	339	337	16	0.047	741	0.047[c]
17-Jun	166	166	12	0.072	690	0.072[c]
24-Jun	169	169	7	0.041	521	0.041[c]
Total	1,741	1,717	86	0.050		0.062[e]

[a] USGS Gage 14216000 Lewis River Above Muddy River Near Cougar, WA.

[b] Combined efficiency measured during the month of March (similar average weekly flow).

[c] No adjustment made to measured weekly efficiency.

[d] Combined efficiency measured during the weeks of 15-Apr through 29-Apr (similar average weekly flow).

[e] Average adjusted season efficiency.

Table 3.1-3. Index estimates of fish (adipose fin intact) passing the Eagle Cliff screw trap by species (bootstrap and sum of discrete interval method) from 13 March to 30 June, 2018.

Species	Capture Efficiency Applied[a]	Bootstrap Mean Total Estimate	95% CI +/-
Coho (≥60 mm FL)	0.062	22,974	4,509
Coho (<60 mm FL)	0.062	27,865	5,361
Chinook (≥60 mm FL)	0.062	588	218
Chinook (<60 mm FL)	0.062	2,088	553
Rainbow/Steelhead (≥60 mm FL)	0.062	3,195	767
Cutthroat (≥60 mm FL)	0.062	1,365	385
Sum of Discrete Interval Method (Volkhardt et al. 2007)			
Species		**Total Estimate**	**95% CI +/-**
Coho (≥60 mm FL)		27,637	6,191
Coho (<60 mm FL)		33,436	8,940
Chinook (≥60 mm FL)		811	370
Chinook (<60 mm FL)		2,015	655
Rainbow/Steelhead (≥60 mm FL)		4,210	1,664
Cutthroat (≥60 mm FL)		1,625	535

[a] Average adjusted season efficiency during individual species' periodicity.

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 juvenile coho captured at the FSC and released them back upstream at the head of Swift Reservoir. This was done to bolster sample size of ODS estimates. A total of 1,073 coho, 408 Chinook, 439 steelhead, and 96 cutthroat juveniles were tagged and released at the head of Swift Reservoir for analysis. It is important to note that within each species pooled group exists different cohorts of fish from both the Eagle Cliff screw trap and Swift Reservior FSC; especially with coho and steelhead. The bootstrapping methodology was applied to find both the mean and variances of total number fish per species entering Swift Reservoir during 2018. It was estimated that 150,266 coho, 19,290 Chinook, 17,718 steelhead, and 4,713 cutthroat juveniles entered Swift Reservoir during 2018 (Table 3.1-4). These estimates only consider fish parr size and greater because fry were not be PIT tagged. Comparing these estimates to the number of juveniles estimated to pass Eagle Cliff during screw trapping operations in 2018 reveals that the majority of juvenile fish enter Swift Reservoir during times when the screw trap was not in operation and/or from immediate reservoir tributaries.

Table 3.1-4. Estimates of total fish (adipose fin intact and ≥60 mm FL) entering Swift Reservoir during 2018 by species (bootstrap method).

Species	Tags Released	Tags Recaptured at FSC	Capture Efficiency Applied	Total untagged fish captured at FSC[a]	Bootstrap Mean Total Estimate	95% CI +/-
Coho	1,073	290	0.270	40,433	***150,266***	**14,876**
Chinook	408	97	0.238	4,552	***19,290***	**3,501**
Steelhead	439	191	0.435	7,690	***17,718***	**1,876**
Cutthroat	96	18	0.188	854	***4,713***	**2,243**

[a] Iincludes parr and smolt life-stages; no fry were PIT tagged.

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):

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

With associated variance estimator:

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

And 95% Confidence Interval:

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

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
$\bar{y}$ = 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 2018, and sample rates were set to 100% for a majority of the year. Subsampling occurred on 64 days of operation, from May 5th through July 7th. 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 and error.

3.2.2 Results/Discussion

A total of 57,829 (95% CI range: 50,704 to 64,951) salmonids were captured by the FSC in 2018 (Table 3.2-1). Of these fish, approximately 55,340 were transported and released downstream of Merwin Dam

Table 3.2-1. Estimated monthly and annual totals of all species collected at the FSC in 2018.

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	45	1119	195	88	0	9	539	0	1	29	0	0	1	48	0	0	55	**2129**
February	17	314	98	20	0	34	967	0	0	27	0	0	0	90	0	1	159	**1727**
March	198	732	163	1	0	138	1613	1	0	29	0	1	0	43	1	1	240	**3161**
April	482	619	1694	0	17	47	593	1	4	810	0	6	0	136	8	1	706	**5124**
May	67	627	18271	0	4	24	162	1	4	6646	0	1	2	319	8	2	548	**26686**
June	39	131	13674	0	10	185	170	1	5	300	0	2	0	184	0	1	364	**15070**
July	2	85	342	0	0	27	25	3	1	14	0	0	0	6	0	0	6	**511**
August																		
September																		
October	1	22	134	7	0	1	77	0	0	1	0	4	0	0	0	1	1	**249**
November	79	737	1122	45	0	4	79	6	2	6	0	4	1	16	0	0	3	**2104**
December	68	576	346	26	0	0	25	0	1	7	0	1	0	12	1	0	5	**1068**
Annual Total	**998**	**4962**	**36039**	**187**	**31**	**469**	**4250**	**13**	**18**	**7869**	**0**	**19**	**4**	**854**	**18**	**7**	**2087**	**57825**

Table 3.2-2. Estimated annual totals of species transported downstream in 2018.

Coho				**Spring Chinook**				**Steelhead**					**Cutthroat**			**Bull Trout**	**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**	
998	4843	35880	0	31	462	4187	0	13	18	7863	0	19	4	854	18	0	146	55,336

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	998	0	998
Coho Parr	4,964	164	4,800 - 5,128
Coho Smolt	36,039	4,666	31,373 - 40,705
Coho Adult	187	0	245
Chinook Fry	31	0	31
Chinook Parr	469	90	469
Chinook Smolt	4,250	85	4,165 - 4,335
Steelhead Fry	14	0	14
Steelhead Parr	18	0	18
Steelhead Smolt	7,869	1,770	6,099 - 9,639
Steelhead Adult	0	0	0
Steelhead Kelt	19	0	19
Cutthroat Fry	4	0	4
Cutthroat <13 in	854	149	705 - 1,003
Cutthroat >13 in	18	7	11-25
Bull Trout	7	0	0
Rainbow Trout	2,087	190	1,897 - 2,277
Total	**57,825**	**7,122**	**50,703 - 64,947**

(Table 3.2-2). Juvenile coho accounted for the highest proportion of the overall estimated catch (73.0%), followed by steelhead (13.7%), spring chinook (8.2%) and coastal cutthroat trout (1.5%). A total 2,087 hatchery rainbow trout and 7 bull trout were also collected in 2018 and returned to the reservoir. Approximately 146 hatchery rainbow trout were passed downstream of Merwin Dam during the subsample collection period (May-June).

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 summer maintenance.

3.3.2 Results/Discussion

Overall, the run timing in 2018 followed a normal frequency distribution, with peak migration occurring in mid-May. The late-fall migration component seen in previous years was significantly smaller in 2018, relative to previous years. Across all species and size classes, the most out-migration occurred between March 1st and June 30th. Within this time frame, 98.7% of the steelhead, 87.4% of the coho, 80.0% of the cutthroat, and 62.4% of the chinook were collected relative to the total annual catch (Figures 3.3-1 through 3.3-12). Coho parr demonstrated slightly more evenly distributed migration pattern, with approximately 70% of parr migrating between January 1st and June 30th, and the remaining 30% migrating in the fall.

Coho Size Distributions

An asymmetrical bimodal size distribution was observed for juvenile coho collected at the FSC throughout the first quarter of the year. During the months of January-March, coho fry composed the majority of the catch, with a smaller proportion of the catch being composed of the much larger (220 – 290 mm) 2-year old smolts. The asymmetrical bimodal size distribution transitioned into a normal distribution pattern later in the spring (April – June), with size distributions being relatively evenly distributed about the mean (approximately 165 mm). During this timeframe, the majority (>95 %) 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 (82.1%) had lengths of less than 130 mm (Figure 3.3-11).

Spring Chinook Size Distributions

The majority of spring Chinook for lengths observed in 2018 positively correlate with hatchery smolt releases associated with the acclimation program. This suggests the majority of spring Chinook collected by the FSC in 2018 originated from the acclimation plants that occurred during July and August of 2017. However, a smaller proportion (>10%) of the spring Chinook captured in 2018 exhibited fork lengths of <120 mm (Figure 3.3-12). It is suspected that these smaller fish are the progeny of spring Chinook adults released into the Upper Lewis River in 2017.

Steelhead Size Distributions

Steelhead size distributions observed in 2018 were similar to those seen in previous years. The mean fork length for steelhead captured in 2018 was 223 mm with the majority (>98 %) having fork lengths that were >150 mm (Figure 3.3-13). During the peak spring-time migration period (April – June), the mean steelhead fork length was approximately 210 mm (Figure 3.3-13). Steelhead captured during the remainder of the year exhibited a broad spectrum of size classes (Figure 3.1-13).

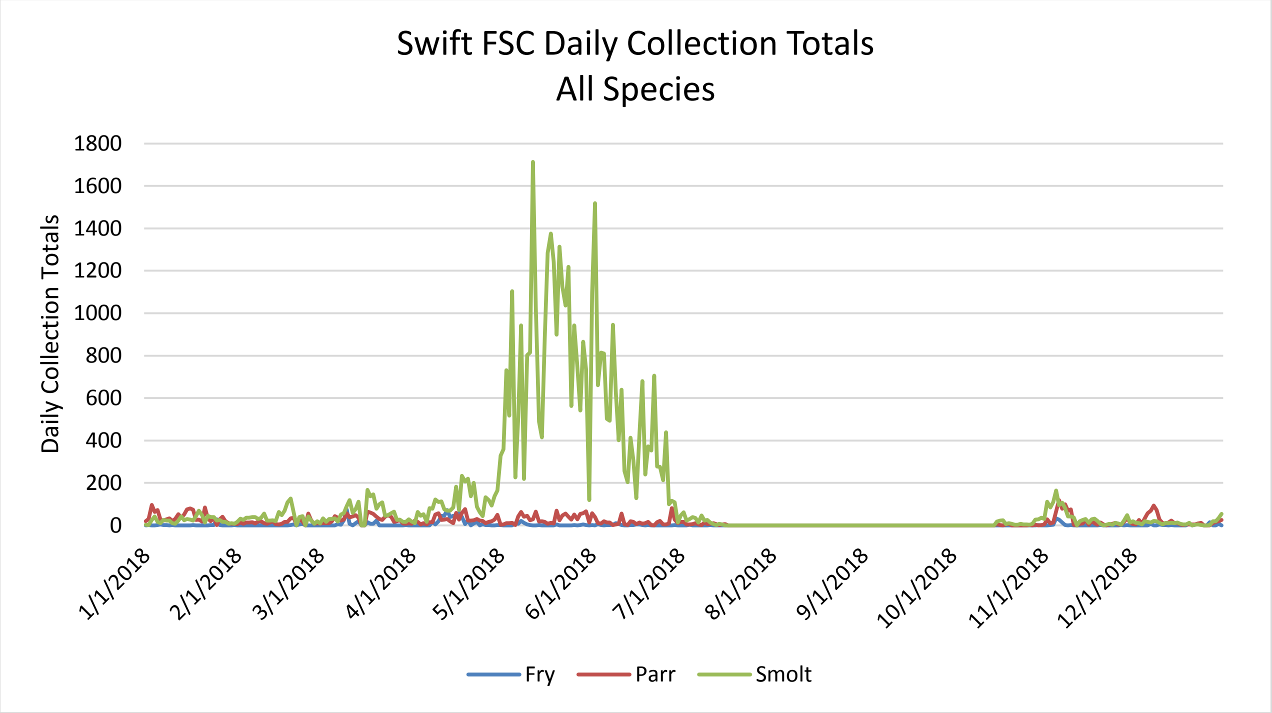


Figure 3.3-1. Estimated daily collection totals for all species at Swift FSC.

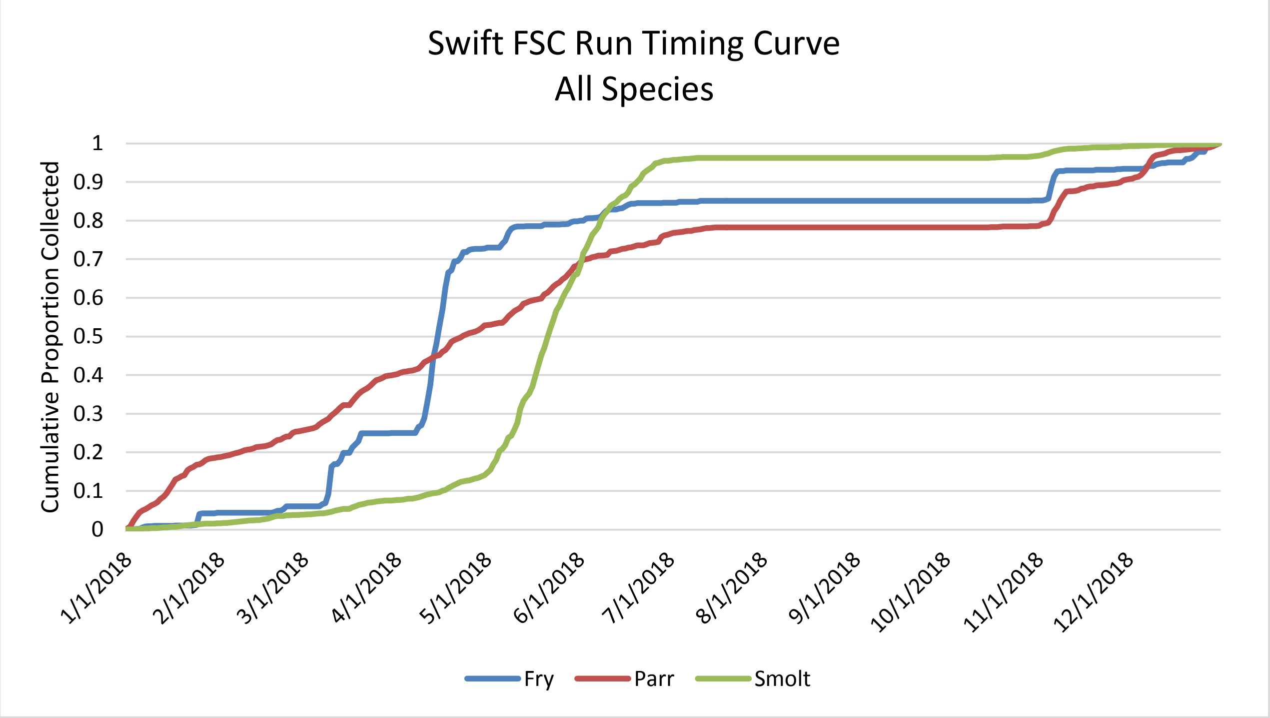


Figure 3.3-2.   Cumulative migration timing among all species at Swift FSC.

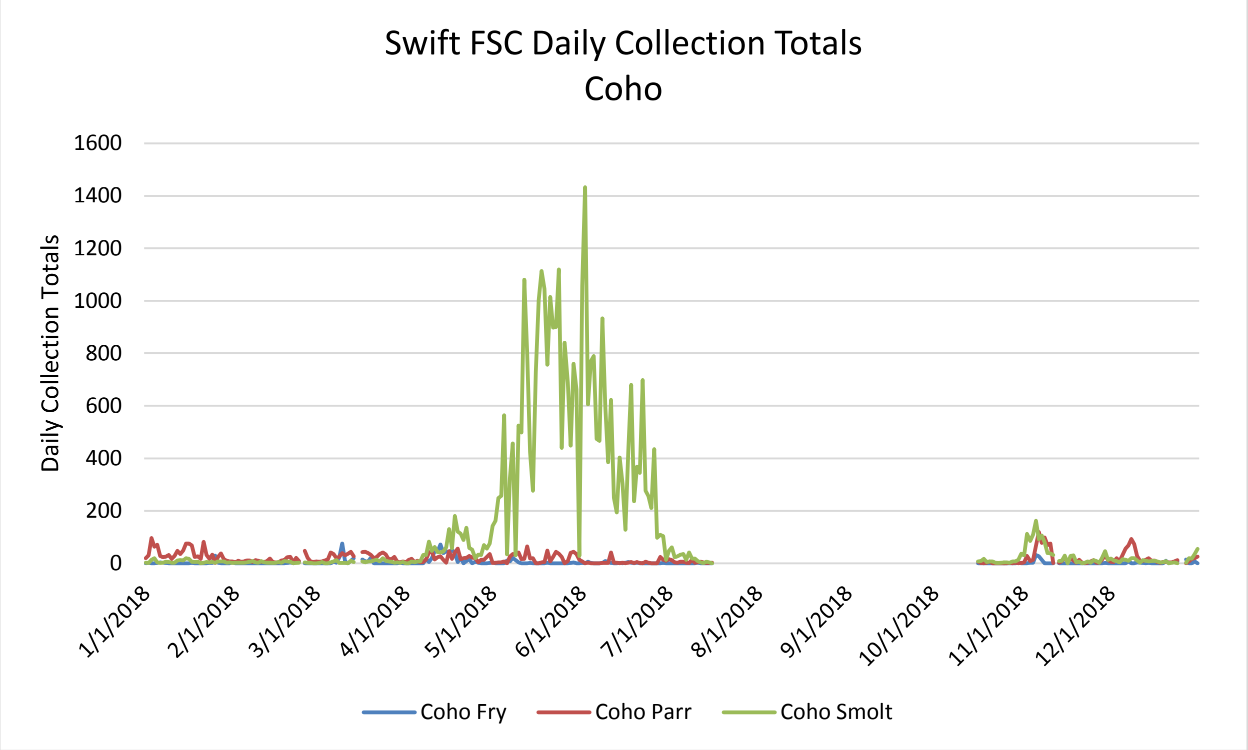


Figure 3.3-3. Estimated daily collection totals of juvenile coho at Swift FSC.

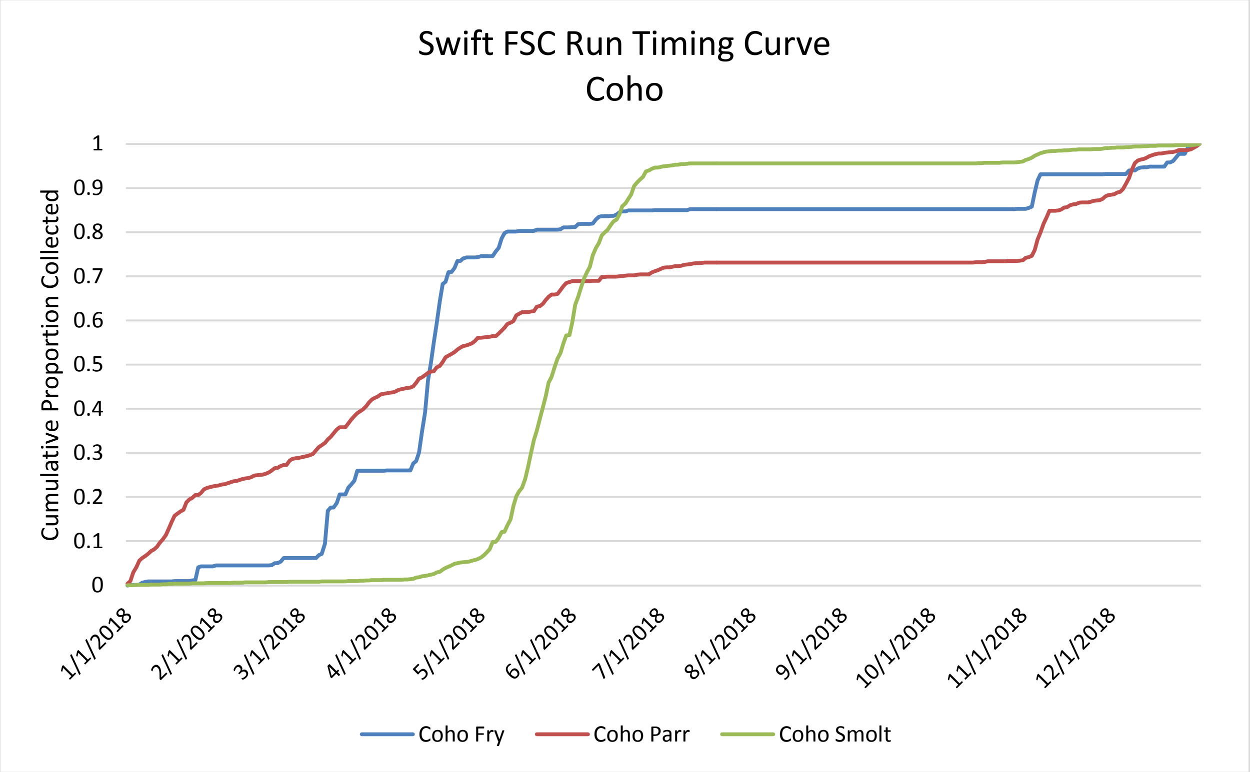


Figure 3.3-4. Cumulative migration timing of juvenile coho at Swift FSC.

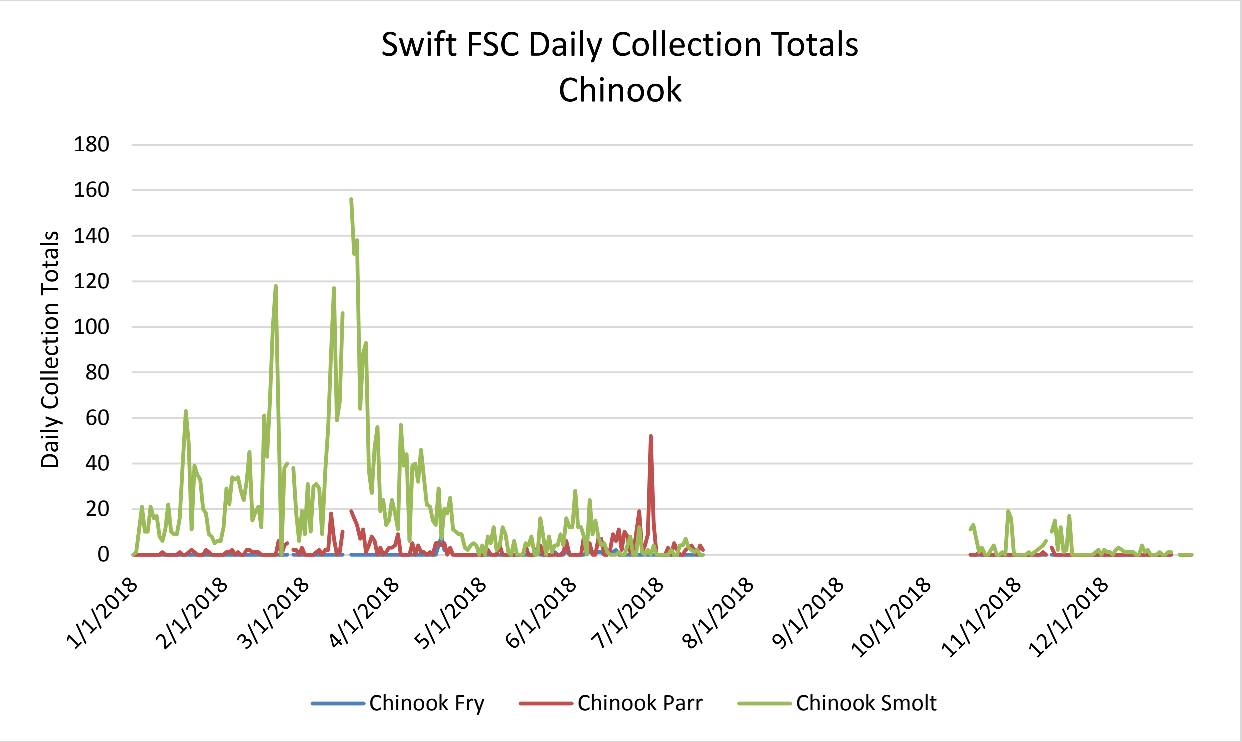


Figure 3.3-5. Estimated daily collection totals of juvenile Chinook at Swift FSC.

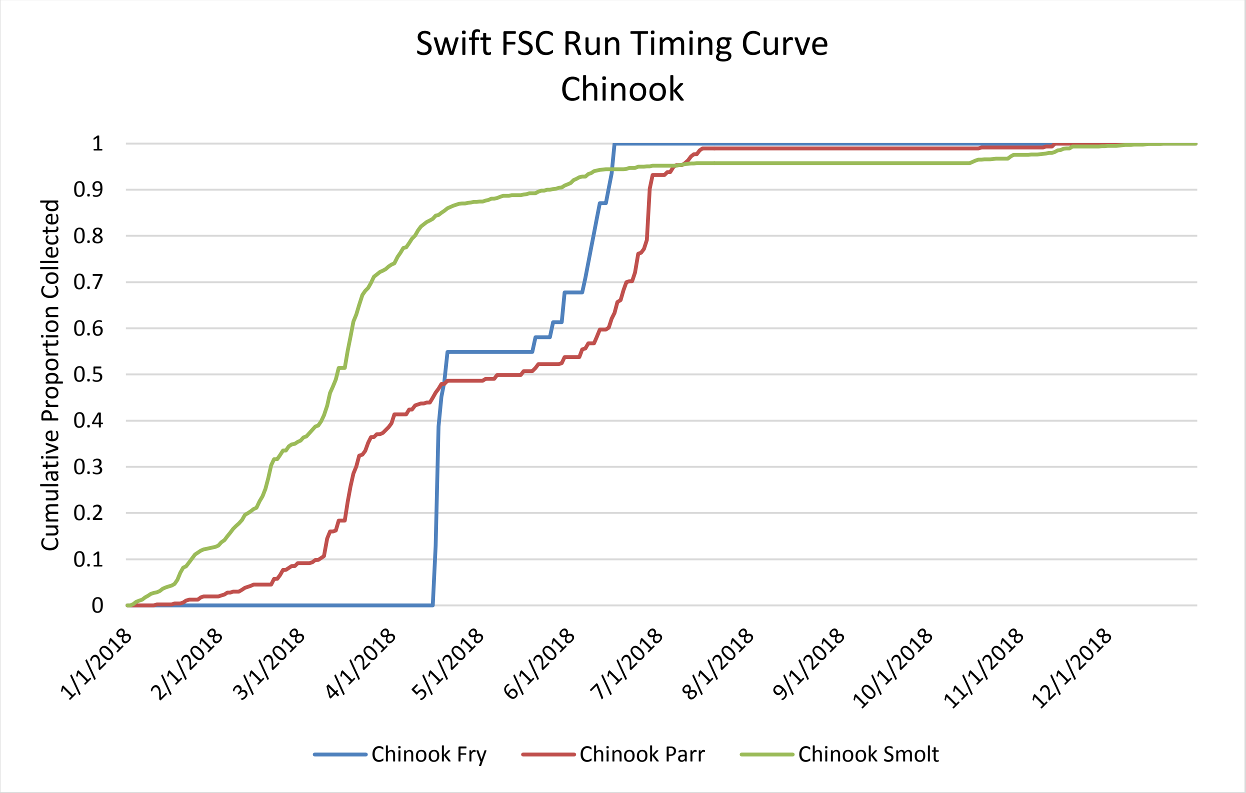


Figure 3.3-6. Cumulative migration timing of juvenile Chinook at Swift FSC.

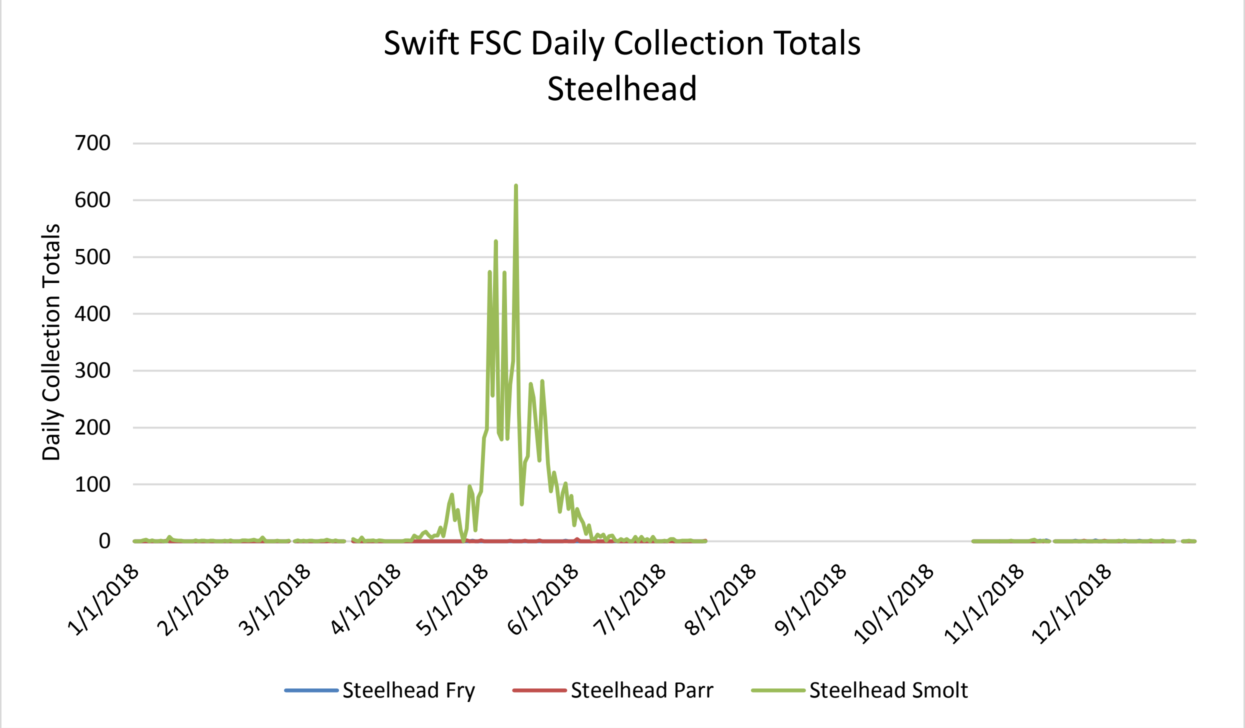


Figure 3.3-7. Estimated daily collection totals of juvenile steelhead at Swift FSC.

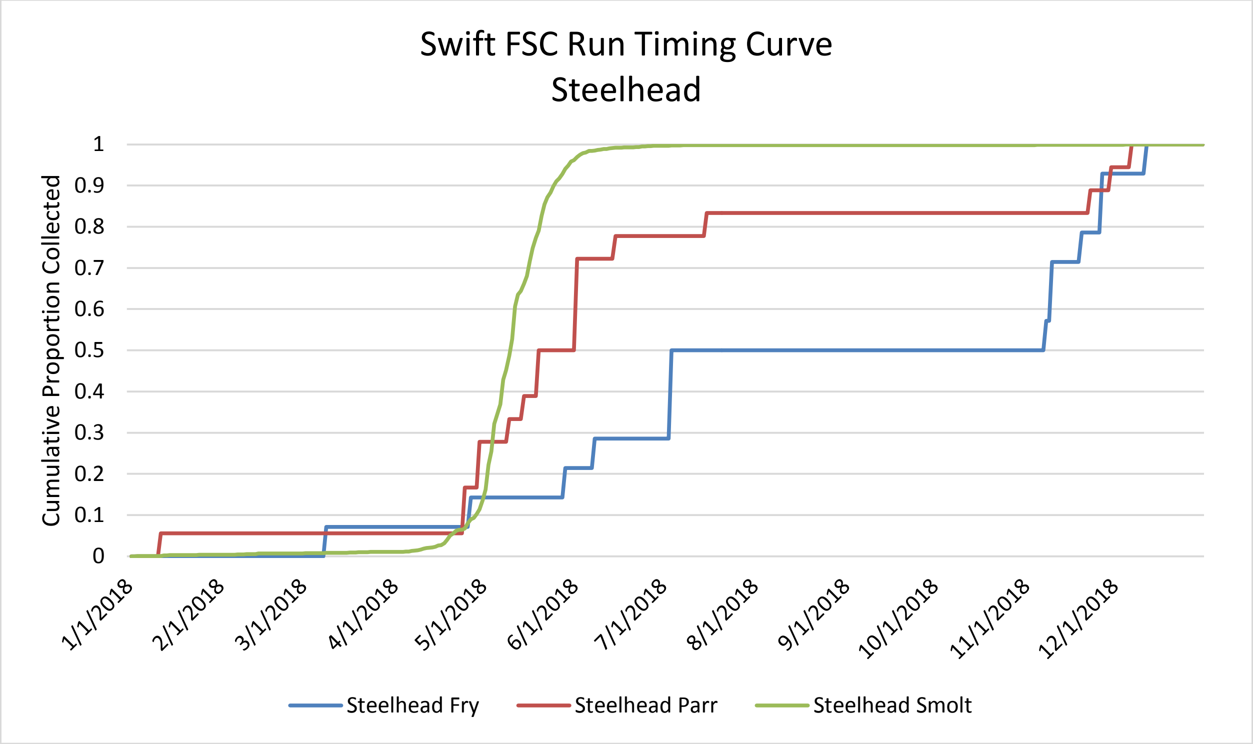


Figure 3.3-8. Cumulative run timing of juvenile steelhead at Swift FSC.

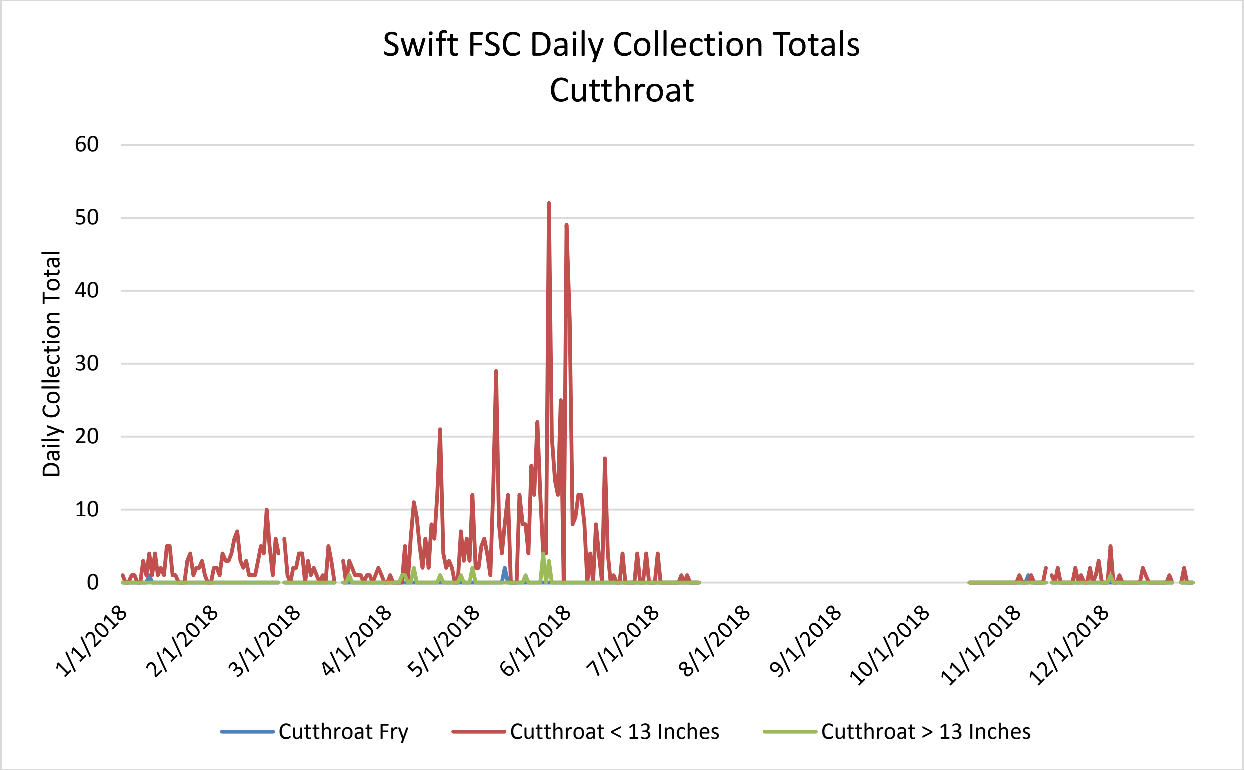


Figure 3.3-9. Estimated daily collection totals of juvenile cutthroat trout at Swift FSC.

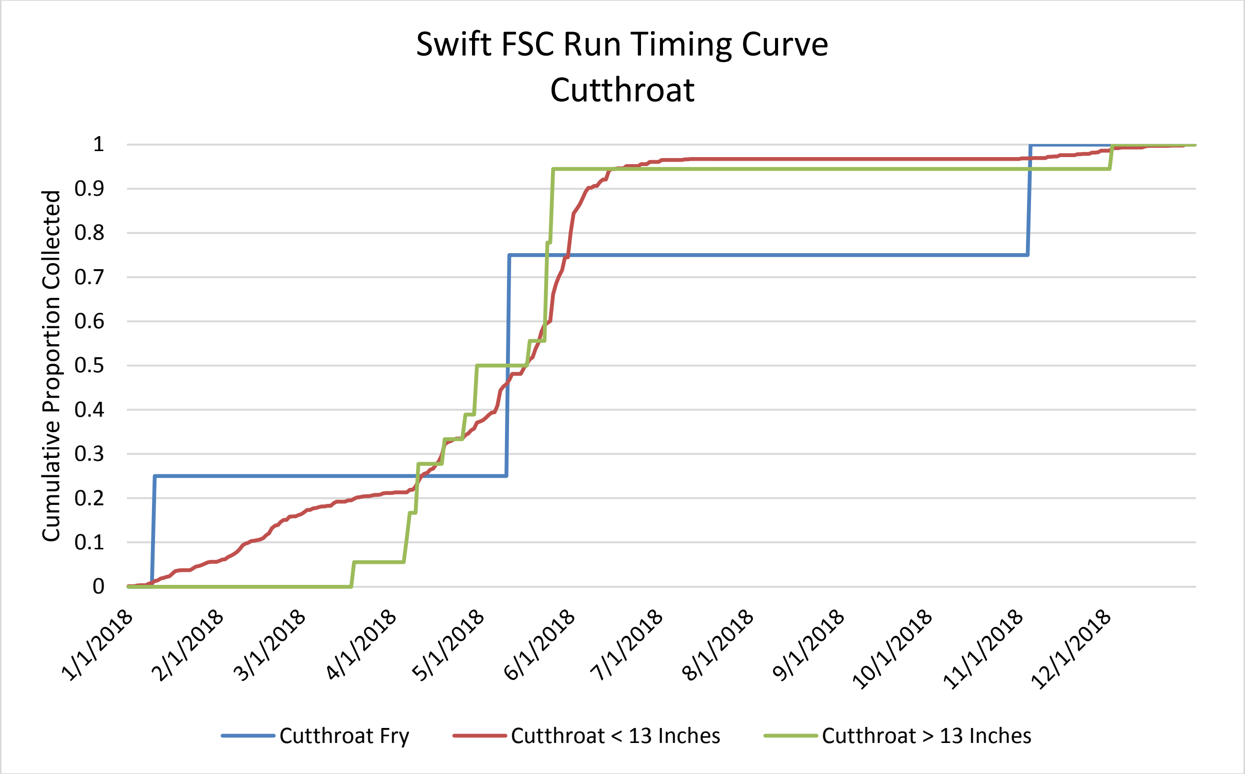


Figure 3.3-10. Cumulative run timing of juvenile cutthroat trout at Swift FSC.

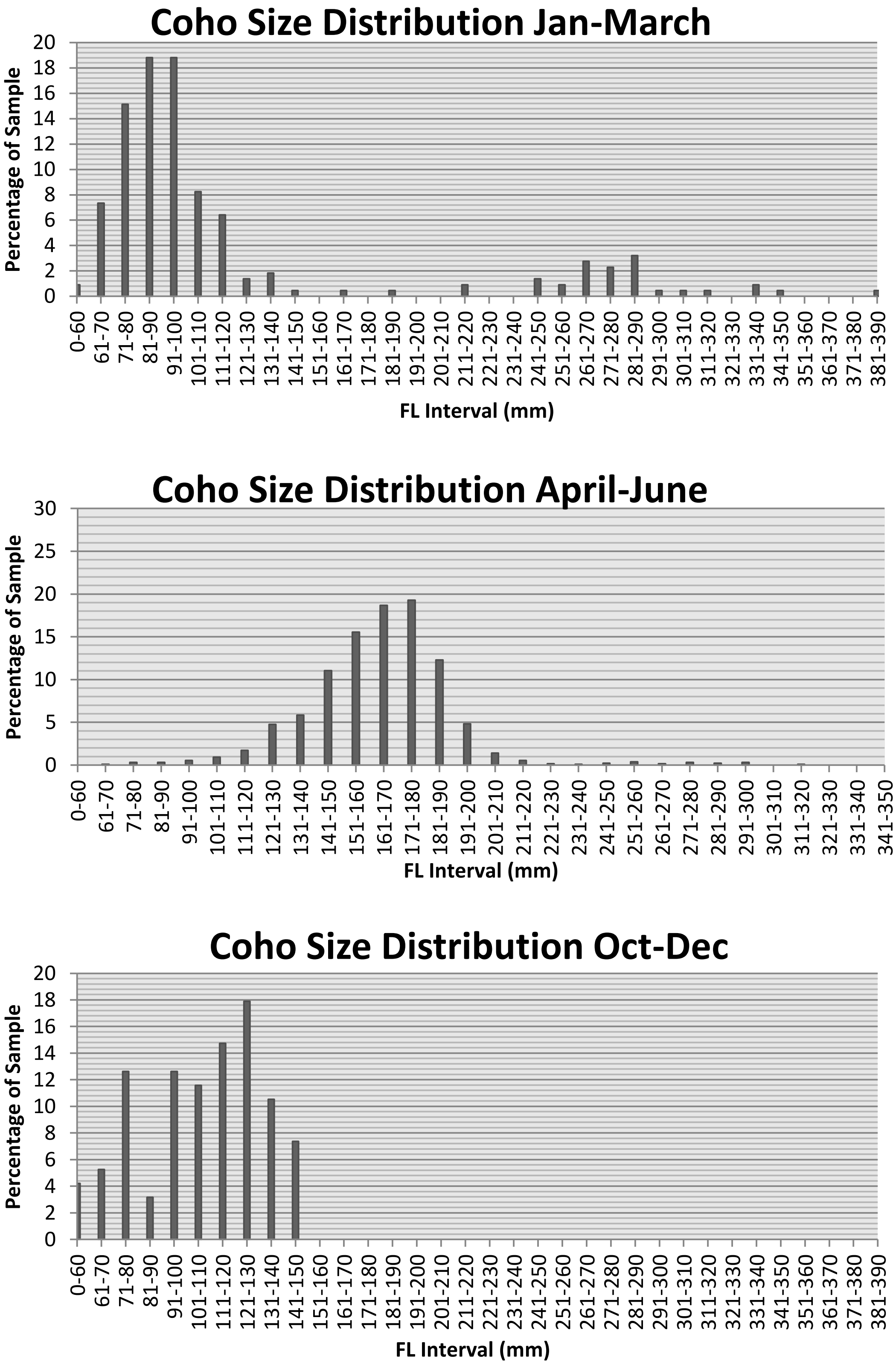
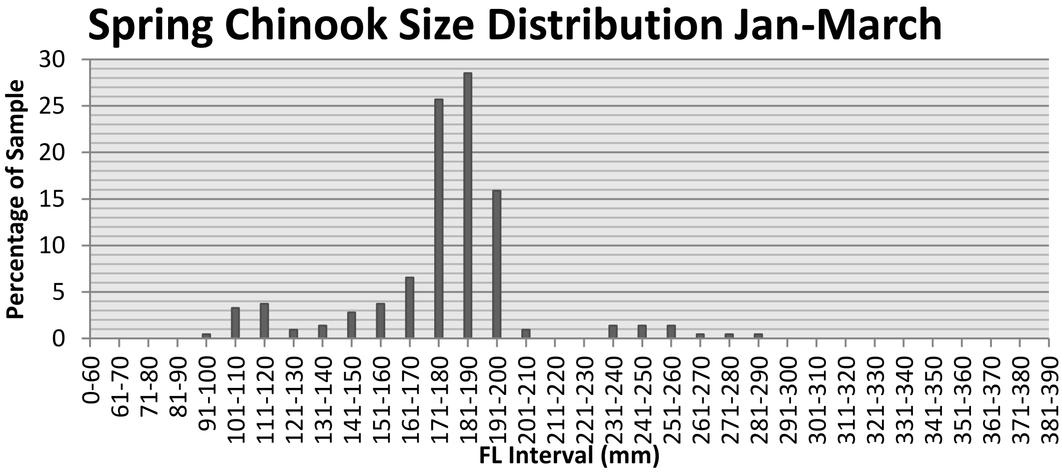
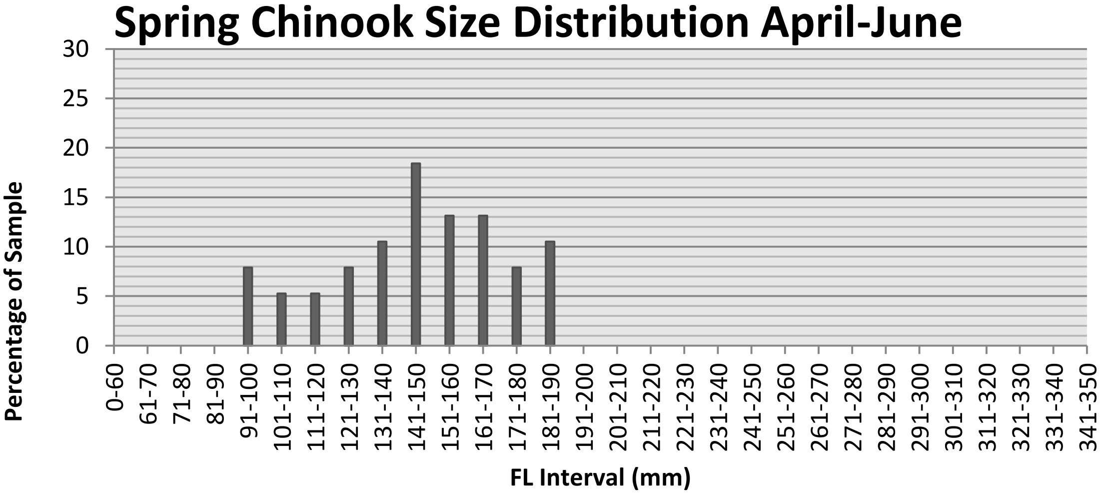


Figure 3.3.11. Size distribution of coho migrants collected at the Swift FSC in 2018.





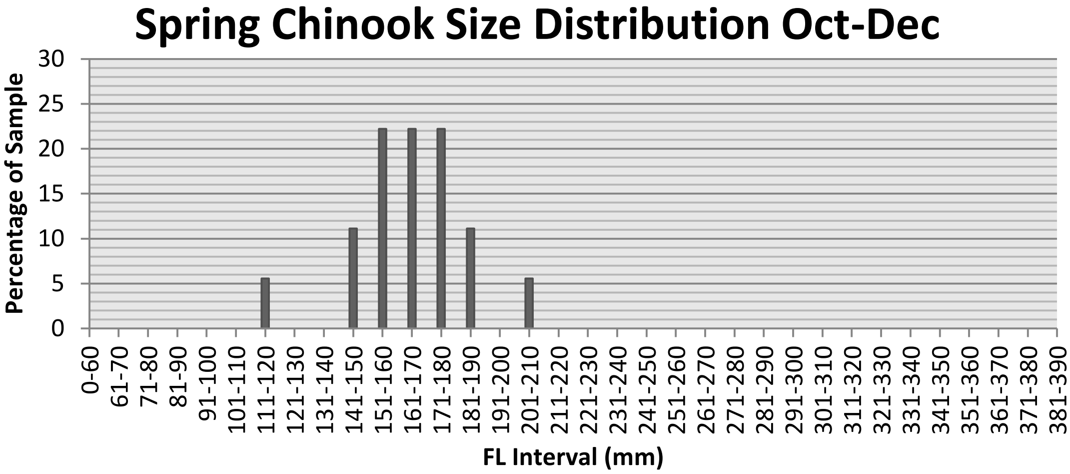
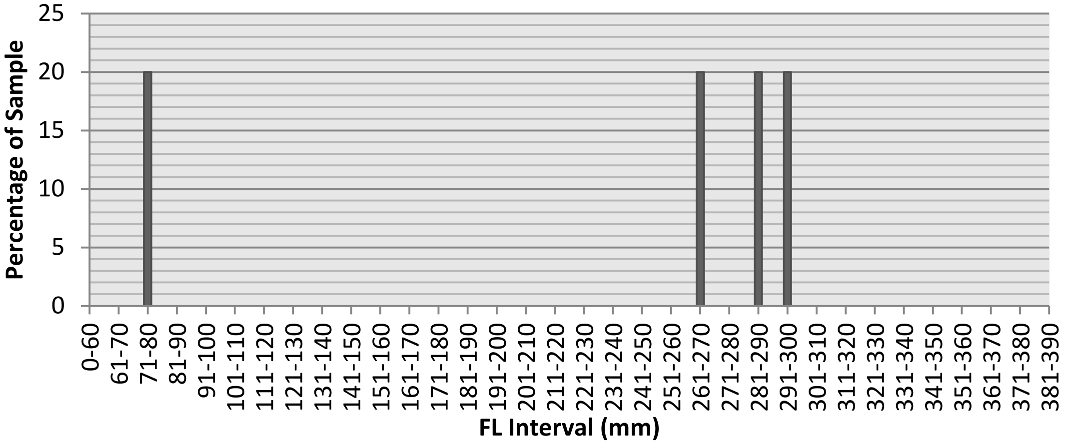
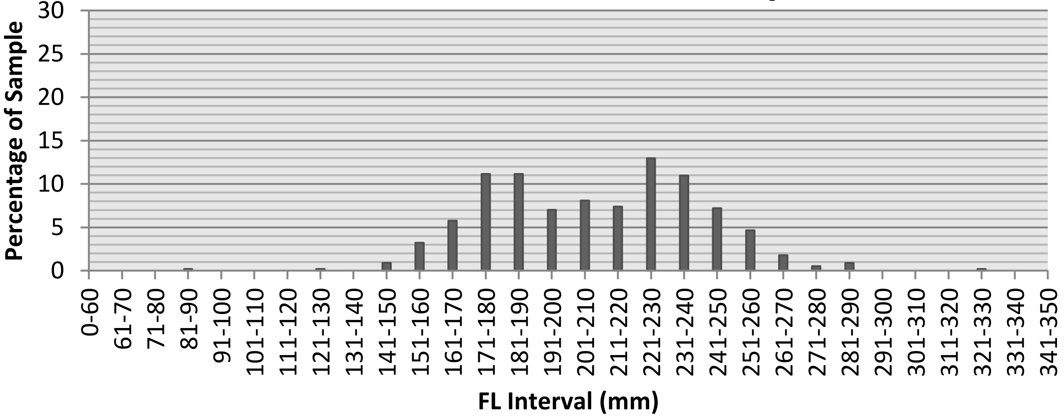


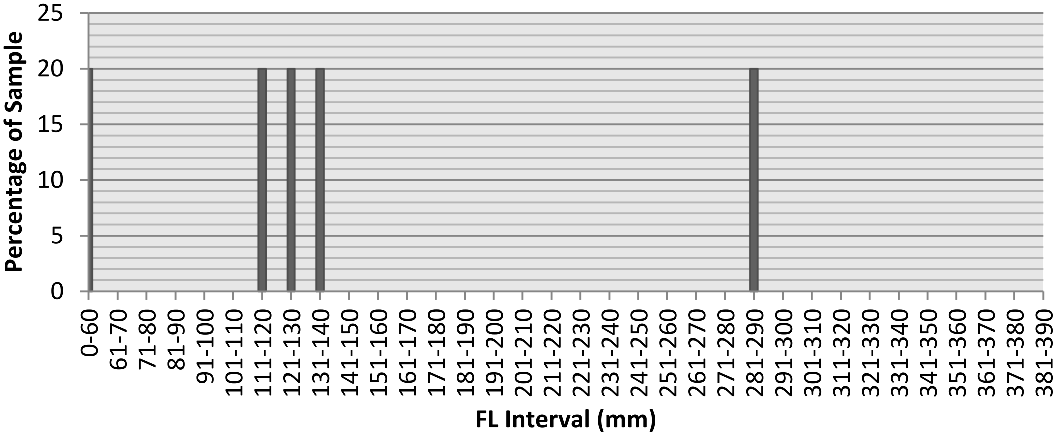
Figure 3.2-12. Size distribution of spring Chinook migrants collected at the Swift FSC in 2018.



Steelhead Size Distribution Jan-March



Steelhead Size Distribution April-June



Steelhead Size Distribution Oct-Dec

Figure 3.2-13. Size distribution of steelhead migrants collected at the Swift FSC in 2018.

3.4 FSC Collection Efficiency

3.4.1 Overview

Section 9.2.1(c) of the Settlement Agreement requires the Licensee to evaluate the collection efficiency of the Swift Floating Surface Collector. Objective 2 of the M&E Plan addresses collection efficiency (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 entrance that was thought to be influenced by flow entering the FSC. A performance standard of 95% or greater for out-migrating smolts[5] was agreed upon for P_{CE}.

Typically each year the collection efficiency study is done via biotelemetry in order to better analyze fish movements near the FSC and to delineate whether or not a fish was considered available for capture (i.e. if it entered the ZOI). During the 2017 collection efficiency study (Anchor QEA 2018) a subset of PIT-tagged only fish were released congruently with test fish that were both acoustically and PIT tagged (dual tagged). The collection rates between PIT tagged only fish and dual tagged fish were similar between respective species and with no detected significant differences. For various reasons, the 2017 FSC collection efficiency report was delayed and provided by the contractor to PacifiCorp in the spring of 2018. Because of this there was not ample enough turnaround time for PacifiCorp to facilitate a full biotelemetry study in spring 2018. Given the PIT tagged only and dual tagged fish displayed similar capture rates PacifiCorp felt comfortable in carrying out a collection efficiency study using PIT tags only during the 2018 migration season.

3.4.2 Methods

Tagging and Release:

Similar to previous year, out-migrants captured at the FSC were used as test fish during the study. Test fish were mildly sedated, identified by species, measured for fork length (mm), and PIT tagged just above the pelvic girdle. Once tagged, test fish were placed in recovery tanks on board the FSC and held for a minimum of 24 hours. Test fish were then inspected for livelihood/injury and tag retention before being transferred to a large cooler equipped with an oxygen stone and transported up reservoir by boat. Test fish were then released near the head of Swift Reservoir towards the shore shoreline adjacent to Swift Forest Camp boat launch. If recaptured, test fish PIT tags were recorded by a series of two PIT tag antennae arrays within the FSC and uploaded to PTAGIS daily.

Sample Size and Tagging Schedule:

Minimum sample sizes were determined by using 2017 system survival rates per species (the percentage of tags released at the head of the reservoir that were subsequently captured by the FSC), a selected confidence interval of 5% and an α-value of 0.05 (Equation 3.4-3). Tagging schedule was determined per species during a 4-6 week window about the respective species run timing peak as observed in past seasons.

$$\text{Given: } \boldsymbol{CI = Z_{\frac{\alpha}{2}} * \sqrt{Var(S_{RES})}} \qquad \text{Equation 3.4-1}$$

---

[5] 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.

and that: $$\boldsymbol{Var(S_{RES})} = \frac{\left(\frac{n_2}{n_1}\right) * \left[1-\left(\frac{n_2}{n_1}\right)\right]}{n_1} \quad \text{Equation 3.4-2}$$

then: $$\boldsymbol{n_1} = \frac{\left(Z_{\frac{\alpha}{2}}\right)^2 * \left\{\left(\frac{n_2}{n_1}\right) * \left[1-\left(\frac{n_2}{n_1}\right)\right]\right\}}{CI^2} \quad \text{Equation 3.4-3}$$

Where:

$\boldsymbol{CI} =$ Confidence Interval
$\boldsymbol{Z_{\frac{\alpha}{2}}} =$ Z-value of normal distribution with given α-value.
$\boldsymbol{n_1}$ = number of tagged fished released or **sample size**.
$\boldsymbol{n_2}$ = number of tagged fish recaptured.
$\boldsymbol{S_{RES}} = \left(\frac{n_2}{n_1}\right)$

Collection Efficiency Calculation:

Collection efficiency in past years was determined through biotelemetry as the portion of tagged fish that entered the ZOI and were subsequently captured by the FSC. This collection efficiency metric is part of the more broad metric Reservoir Survival (S_{RES}), which is a part of Overall Downstream Survival (ODS) - covered in Section 3.7 of this report. S_{RES} is defined as the proportion of tagged fish released at the head of the reservoir that are successfully captured by the FSC. S_{RES} is a joint probability of multiple other ratios and can be written as:

$$\boldsymbol{S_{RES} = P_{RES} * P_{ZOI} * P_{CE}} \quad \text{Equation 3.4-4}$$

Where:

$\boldsymbol{P_{RES}} =$ Proportion of tagged fish released at the head of the reservoir that survive to the forebay.

$\boldsymbol{P_{ZOI}} =$ Proportion of tagged fish that made it to the forebay that enter the ZOI.

$\boldsymbol{P_{CE}} =$ Collection efficiency; proportion of tagged fish that entered the ZOI that were captured by the FSC.

Collection efficiency ($\boldsymbol{P_{CE}}$) is not obtainable through the use of PIT tags as there is no way of knowing whether a PIT tag has entered the ZOI or not. However, it is possible to obtain $\boldsymbol{S_{RES}}$ exclusively with PIT tags because the two points of concern are the release point (head of reservoir) and the recapture point (PIT tag antennae within the FSC). It is important to note that $\boldsymbol{S_{RES}}$ is a joint probability of $\boldsymbol{P}_{RES}$, $\boldsymbol{P_{ZOI}}$, and $\boldsymbol{P_{CE}}$ and that each of these constituents (as they are proportions) will likely never be 100% or 1. Given this, $\boldsymbol{S_{RES}}$ can never be greater than $\boldsymbol{P_{CE}}$. For these reasons, in 2018, Pacificorp used $\boldsymbol{S_{RES}}$ as a surrogate for $\boldsymbol{P_{CE}}$ realizing it is conservative estimate; meaning the actual $\boldsymbol{P_{CE}}$ is almost certainly larger than what is reported for $\boldsymbol{S_{RES}}$. To help conceptualize this, a schematic of the equation is provided below (Figure 3.4-1).

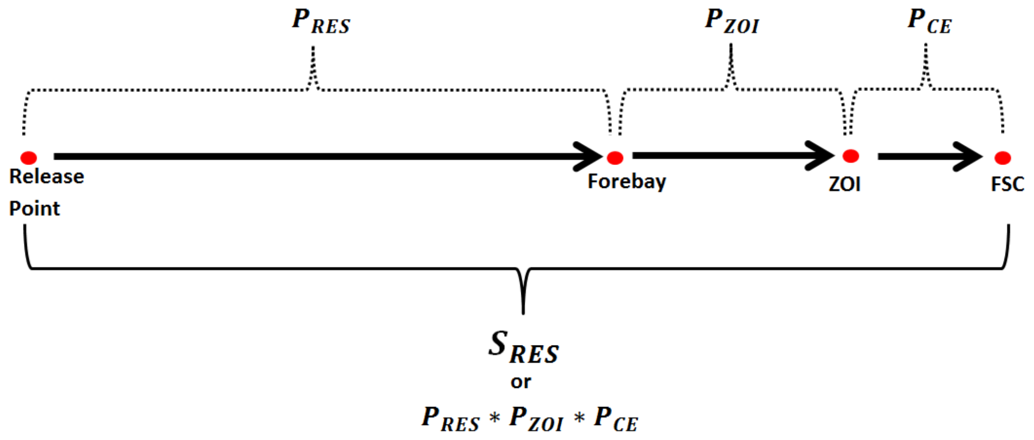


Figure 3.4-1: A schematic of S_{RES} and the different probabilistic constituents it consists of. The schematic is shown in a linear fashion of a successfully passed fish whom would start at the release point then proceed to the forebay, zone of influence (ZOI), and finally the FSC.

3.4.3 Results

Distribution of Tags:

The required minimum sample size per species was calculated based on the respective species S_{RES} value observed in 2017 (Anchor QEA 2018). The required minimum sample sizes and actual sample sizes used are shown below in Table 3.4-1.

Table 3.4-1. Minimum required sample size by species given 2017 S_{RES} values with α = .05 and the actual sample sizes used.

Species	2017 Observed S_{RES}	Minimum Sample Size	Sample Size Used 2018
Coho	0.227	270	484
Spring Chinook	0.073	104	396
Steelhead	0.149	195	278

The release timing for test fish is shown below in Figure 3.4-2. Peak run timing as observed by captures at the FSC occurred during mid-March for Chinook and mid-May for both coho and steelhead. Timing the tagging of test fish to represent the general run timing curves of a given species continued to be a challenge as there are many different environmental factors that affect run timing from year to year. As a result, the majority of tagging and release of all species were conducted during the month prior to the respective species peak migration. PIT tag interrogations occurring up to December 31, 2018 were to be designated as recaptures for the study. In past studies the batteries in active tags (radio/acoustic) typically lost charge and were no longer active by the beginning of July. In 2018, no PIT tags associated with this study were collected at the FSC after June 24, 2018. The release schedule and recapture of test species at the FSC are shown in Figure 3.4-2 as cumulative percentages. There were no test fish captured after April 22, 2018 for Chinook, May 30, 2018 for steelhead, and June 24, 2018 for coho.

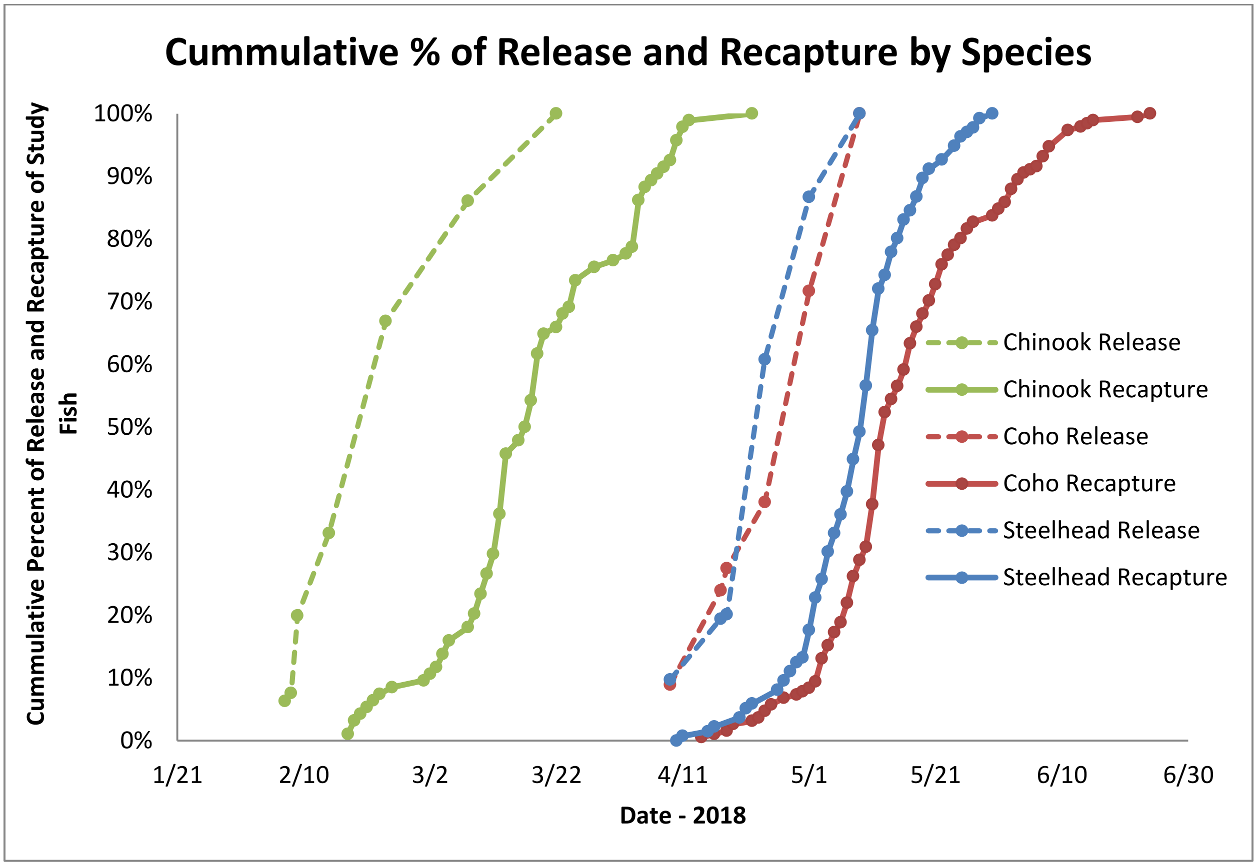


Figure 3.4-2: Cumulative percent of release and recapture of test fish per species versus time.

The resulting collection efficiency results for 2018 are shown below in Table 3.4-2. To calculate $\boldsymbol{S_{RES}}$, all data were pooled together as one set per species. As previously mentioned, $\boldsymbol{S_{RES}}$ was used in 2018 as a serogate for collection efficiency due to the use of PIT tags only..

Table 3.4-2. The 2018 collection efficiency results with associated confidence intervals are shown below. For comparison, S_{RES} values for the 2017, 2016, and 2015 acoustic telemetry studies are also shown. [1]The 2018 S_{RES} was used as a serogate for collection efficiency.

Species	**Released**	**Recaptured**	**2018 S_{RES}**	**2017 S_{RES}**	**2016 S_{RES}**	**2015 S_{RES}**
Chinook	396	94	***23.7%*** **± 4.2%**	7.3% ± 4.9%	0%	0%
Coho	484	191	***39.5%*** **± 4.4%**	23% ± 6.2%	19% ± 6.0%	9.3% ± 4.8%
Steelhead	278	136	***48.9%*** **± 5.9%**	15% ± 5.3%	17% ± 12%	17% ± 11%

Although collection efficiencies are being reported as one set of data per species we recognize that there are variations in collection efficiency between intra-species release groups. The collection efficiencies by release group per species are shown in Figure 3.4-3.

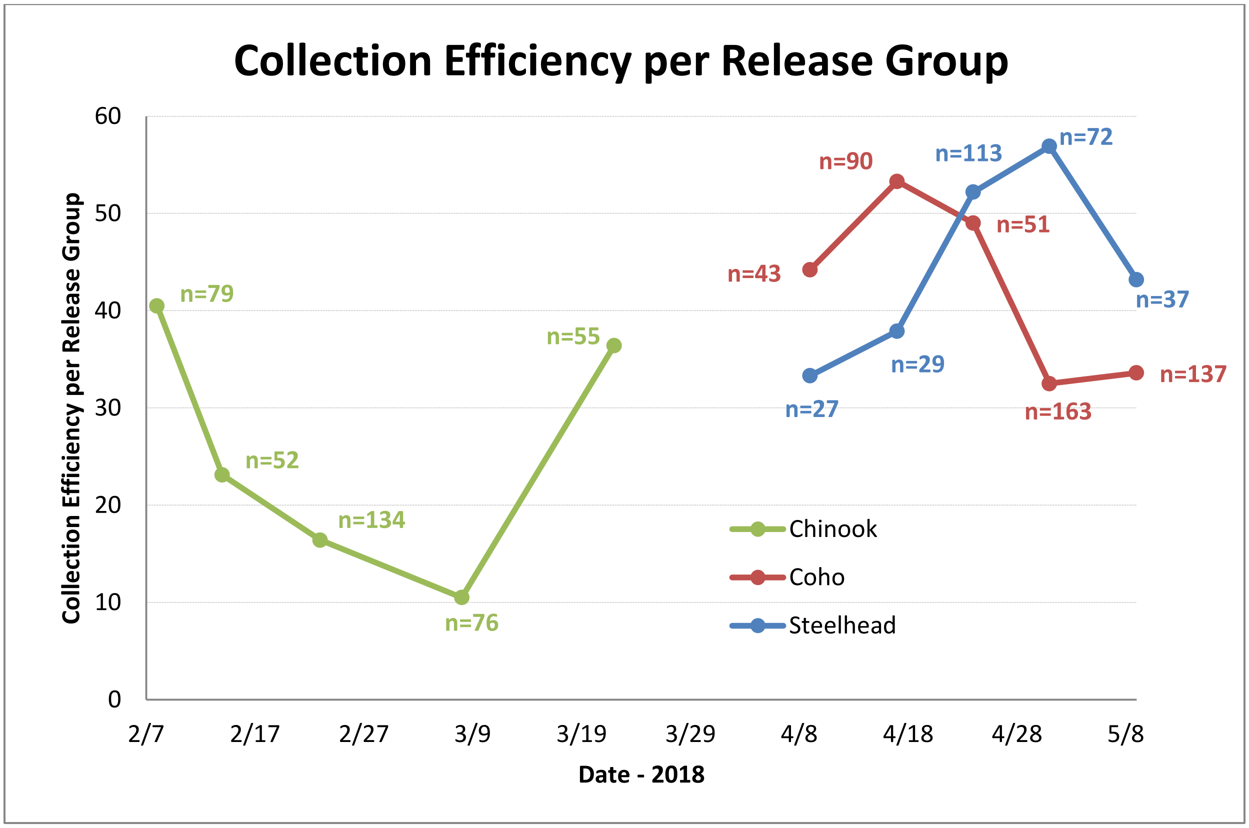


Figure 3.4-3: Collection efficiency values for each release group/tagging event per species. The number of tagged fish per each release group are shown as data labels.

3.4.4 Discussion

The 2018 estimates of $\boldsymbol{S_{RES}}$ revealed the highest rates observed since the commissioning of the FSC. From 2017 to 2018 Chinook saw a $\boldsymbol{S_{RES}}$ percent increase of 225%, coho increased 72%, and steelhead increased 226%. During the 2017 collection efficiency study, contractors also investigated sound intensity in the water around the vicinity of the FSC (Anchor QEA 2018). It was determined that sound conditions in the water exceeded intensities that are thought to deter smolts. It was also found that the major cause of the sound was from the pumps on the FSC that pump out water coming in to the vessel. In late 2017, these pumps were re-programmed to run at a lower rate and in a much “acoustically quieter” arrangement. It is thought that the reduction of operating noise of the FSC could have been a main contributor to the increase in $\boldsymbol{S_{RES}}$, and likely collection efficiency (P_{CE}).

The increase in Chinook $\boldsymbol{S_{RES}}$ could also be attributed to the improved condition of the test fish. The juvenile Chinook used in the study were all from the 2017 releases from the upstream acclimation program. In years prior to 2017, acclimation Chinook captured at the FSC (and used in the 2015, 2016, and 2017 efficiency studies) were generally in poor condition (e.g. BKD, high copepod presence, intense smoltification). In 2017, acclimation Chinook were released much earlier in the season and at a much smaller size than years prior resulting in a noticeably healthier stock (PacifiCorp 2017).

As previously mentioned, the resulting 2018 $\boldsymbol{S_{RES}}$ were used as a serogate for P_{CE} , and are likely more conservative than collection efficiencies reported in previous years. Reservoir survival includes many other factors like reservoir predation, prolonged post-tagging mortality, fish never entering the forebay, or fish never entering the ZOI that past biotelemetry studies accounted for and removed from the collection efficiency calculation, as only fish that entered the ZOI were considered available for collection. To review the 2018 $\boldsymbol{S_{RES}}$ estimates that are being used as surrogates for collection efficiency were 23.7% (±4.2) for Chinook, 39.5% (±4.4) for coho, and 48.9% (±5.9) for steelhead. However, as an exercise and example of how conservative the 2018 estimates are, weighted averages were taken from the 2015-2017 biotelemetry studies of the proportion of fish that made it to the forebay from the release point (i.e. $\boldsymbol{P_{RES}}$) and used to expand the 2018 $\boldsymbol{S_{RES}}$ estimates. In essence, all this does is reduce the amount of tags considered available for collection. The weighted average of the 2015-2017 $\boldsymbol{P_{RES}}$ was 69% for Chinook, 86% for coho, and 72% for steelhead. Applying these $\boldsymbol{P_{RES}}$ values to the 2018 study results in collection efficiencies of 35% (±6) for Chinook, 46% (±5) for coho, and 68% (±6) for steelhead. These should still be considered as somewhat conservative estimates as $\boldsymbol{P_{ZOI}}$ (proportion of fish that enter the forebay that also enter the ZOI) is not accounted for. Furthermore, we took the observed 2017 $\boldsymbol{P_{ZOI}}$ and the 2015-2017 weighted average $\boldsymbol{P_{RES}}$ values for each species and applied them to the 2018 results to get an theoretical estimate of P_{CE} in 2018 (we did not consider the years prior to 2017 for $\boldsymbol{P_{ZOI}}$ due to various changes, such as the guide net, have occurred in the forebay. Since $\boldsymbol{P_{RES}}$ only considers reservoir survival, we felt it appropriate to include multiple years). The 2017 $\boldsymbol{P_{ZOI}}$ values were 83% for Chinook, 92% for coho, and 89% for steelhead. Applying both $\boldsymbol{P_{RES}}$ and $\boldsymbol{P_{ZOI}}$ to the 2018 study data resuled in theoretical collection efficiencies of 42% (±6) for Chinook, 50% (±5) for coho, and 77% (±6) for steelhead. While these collection efficiencies should be taken as inconclusive, we felt it important to give examples of the conservative nature of the 2018 $\boldsymbol{P_{RES}}$ estimates.

3.5 Swift FSC Injury and Survival

3.5.1 Overview

Injury and survival of captured juvenile out-migrants, and adult cutthroat, bull trout, and steelhead (kelts) were monitored daily on the FSC during 2018 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 used 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 and 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 0.15 percent (Table 3.5-3). Juvenile Chinook (parr and smolt) had the highest overall injury rate (0.15%), followed by juvenile coho (0.09%), and steelhead (0.03%). No injuries were observed on any of the Cutthroat that were collected in 2018. Descaling accounted for the greatest proportion of the injuries observed (87.5%%) in all species, followed by open wounds (12.5%) (Figure 3.5-2). These two injury types accounted for all injuries observed at the Swift FSC in 2018. No injuries were observed among coho fry (n=998), Chinook fry (31), steelhead fry (n=14), or cutthroat fry (n=4). 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 0.1%.

PacifiCorp will continue to address the causes of injury in the future. Debris accumulation in the fry tank has been a major source of injury and mortality. In an effort to reduce injury and mortality caused by debris loading in the fry tank, Pacificorp made modifications to the tank design, and incorporated a debris conveyer. These modifications were completed in December of 2018, and so far appear to be effective at reducing debris-induced mortality. PacifiCorp will continue to monitor the efficacy of these modifications into the future. Additional modifications are underway to address debris-induced injury and mortality in both the smolt and adult tanks. If the current modifications to the smolt and adult tanks are deemed insufficient at reducing injury and mortality, 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.

	No. Injured[a]	No. Sampled[b]	Injury Rate (%)
Coho (Fry)	0	998	0.0
Chinook (Fry)	0	31	0.0
Steelhead (Fry)	0	14	0.0
Cutthroat (Fry)	0	4	0.0
Combined (Fry)	**0**	**1,051**	**0.0**
Coho (Parr & Smolt)	16	18,575	0.09 ± 0.04
Chinook (Parr & Smolt)	7	4,392	0.15 ± 0.12
Steelhead (Parr & Smolt)	1	3,642	0.03 ± 0.05
Cutthroat (Parr & Smolt)	0	521	0
Combined (Parr & Smolt)	**27**	**27,130**	**0.09 ± 0.04**
Steelhead Adults	0	69	0.0
Steelhead Kelts	0	19	0.0
Bull Trout	0	7	0.0

[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.

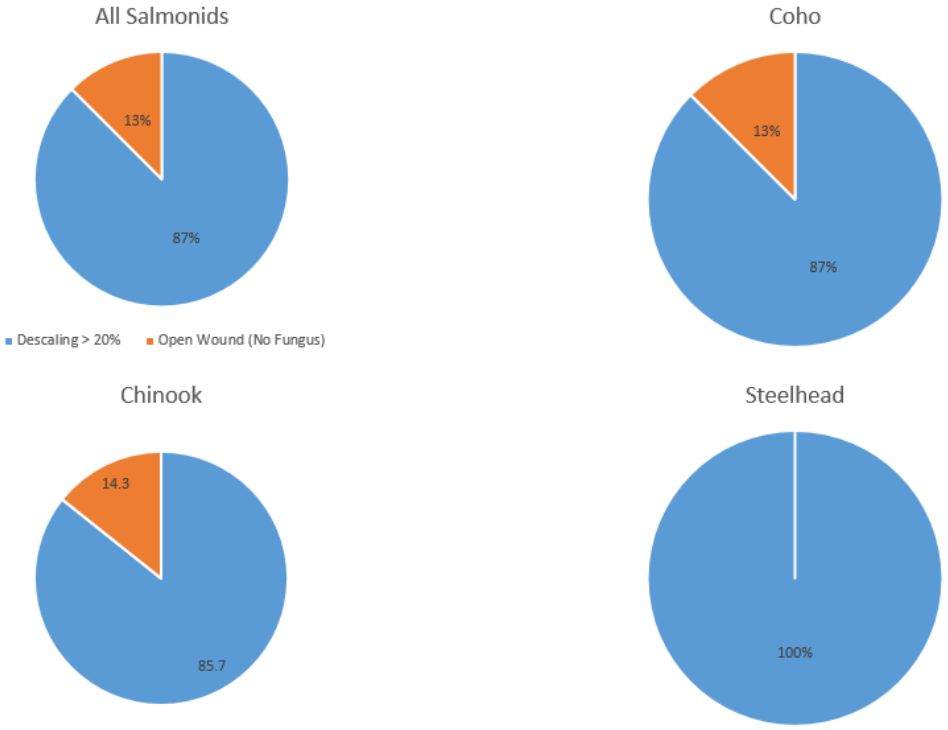


Figure 3.5-2. Composition of injury type occurrences by species. Percentages reflect parr and smolts numbers collected that are referenced in Table 3.5-3.

Survival Rate

Annual survival rates among all target species and life-stages passing through the FSC ranged from 85.7 to 100 percent (Table 3.5-4). Cutthroat trout had the highest overall survival rate (100%) followed by steelhead (99.4%), Coho (98.5%), spring Chinook (98.4 %), adult steelhead (89.7), and Bull Trout (85.7).

No mortality was observed among any species of fry, however it is suspected that fry mortality occurred but was not detected. Fry were redirected to the smolt tanks while modifications were being made to the fry tank, which happened to coincide with peak fry outmigration. It is possible that any injured or deceased fry that entered the smolt tanks may have been predated upon by larger fish, and thus remained undetected.

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 intended to reduce debris-induced mortality have been completed in the fry tank, and additional modifications to the smolt sorting areas and tanks are currently in the final stages of engineering. These modifications are anticipated to be completed in 2019.

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	119	4,625	97.4	98.5± 0.17
Coho Smolts	159	13,950	98.9	
Chinook Parr	7	361	98.1	98.4 ± 0.37
Chinook Smolts	63	4,031	98.4	
Steelhead Parr	0	18	100	99.4 ± 0.13
Steelhead Smolts	6	3,624	99.8	
Cutthroat(< 13 inches)	0	505	100	100
Cutthroat (> 13 inches)	0	16	100	
Total	354	27,130	**Overall:**	98.7± 0.14
Steelhead Adults	8	69	88.4	89.7±6.33
Steelhead Kelts	1	19	94.7	
Bull Trout	1	7	85.7	85.7

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

Species	No. of Mortalities	No. Sampled	Survival% (CS)
Coho Fry	0	998	100
Chinook Fry	0	31	100
Steelhead Fry	0	14	100
Cutthroat Fry	0	4	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%[6]. ODS is defined in Section 4.1.4 of the Settlement Agreement as:

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[6] 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.

> *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 fish entering the Lewis River reservoirs that 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 was to 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 are to 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.

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

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 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, 60 mm 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 percent, tag detection probability of 95 percent 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 percent, 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 2017 study (absent of S_{TRAN}) is shown in Equation 3.7-2.

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

Where:

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

$$\boldsymbol{ODS = S_{RES} * S_{COL}} \qquad \textbf{Equation 3.7-2 (without release ponds - 2017)}$$

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 31, 2018 were included in the 2018 ODS calculations (Table 3.7-1). No dead PIT tagged spring Chinook, coho, cutthroat, or steelhead used in the ODS study were found in the FSC. Hence, S_{COL} was considered 100% for these species during 2018.The Woodland Release Ponds were inspected daily during 2018 for fish mortality. Only two dead PIT tagged spring Chinook pertaining to the ODS study were found in the Woodland Release Ponds, giving spring Chinook an S_{TRAN} value of 0.98. S_{TRAN} for coho, steelhead, cutthroat was 1.0 or 100%.

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-foot-diameter screw trap was operated in the upper Lewis River near Eagle Cliff from 13 March to July 30, 2018. Low numbers of fish were captured by the screw trap in 2018. Because of inadequate numbers of fish to tag, no species received the required 996 tags. During the study period, only 1,073 coho, 408 Chinook, 96 cutthroat, and 438 steelhead were PIT tagged and released. Of the PIT tagged fish, 484 coho, 396 spring Chinook, 36 cutthroat, and 278 steelhead 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 27% (± 2.7%) for coho, 24% (±7.8) for spring Chinook, 19% (± 4.1%) for cutthroat and 43.5% (± 4.6) 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. ODS performance standard for all species is ≥ 80 percent.

Species	Tagged and Released in 2018	FSC Recaptured in 2018	2018 ODS (%) with ±95% CI
Coho	1073	290	27 ± 2.7
Spring Chinook	408	97	23.3 ± 4.1
Steelhead	439	191	43.5 ± 4.6
Cutthroat	96	18	19 ± 7.8 \

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 2017 ODS estimates are summarized below in Table 3.7-2. An additional 15 tagged coho, 12 steelhead, 34 spring Chinook, and 1 cutthroat from the 2017 ODS study were captured by the FSC during 2018.

Table 3.7-2. 2017 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 2017*	FSC Recaptured 2017	2017 ODS (%) with ±95%CI	FSC Recaptured 2018	Total Recaptured (Combined Years)	2017Combined ODS (%) with ±95%CI
Coho	398	71	18 ± 3.4	15	86	22 ± 4.0
Spring Chinook	494	64	13 ± 3.0	34	98	20 ± 3.5
Steelhead	175	27	10 ± 3.6	12	39	14 ± 4.2
Cutthroat	56	3	19 ± 5.9	1	4	7.1 ± 6.7

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 28, 2013, when it was decommissioned for construction of the new passage facility. The new upstream sorting facility at Merwin Dam was considered substantially 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 15,328 fish were captured at the Merwin Trap in 2018 (Table 4.1-1). Among the species collected, summer steelhead accounted for the largest proportion of fish captured (n=5,567) followed by early run coho (n=2,862), winter steelhead (n=2,722), spring Chinook (n=2,106), late coho (n=1,343), fall Chinook (n=623), cutthroat (n=78), and sockeye salmon(n=27. Of the fish captured, several were recaptured fish that hard already passed through the trap once. Recaptured fish counts include 1,785 hatchery summer steelhead, 84 blank wire tag winter steelhead, 13 wild winter steelhead, 5 wild sockeye salmon, and 1 wild summer steelhead.

A total of 3,762 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 of 1,785 summer steelhead were then recaptured at Merwin Trap. Once recaptured, fish were then sent to surplus.

Approximately 16.5% of all early run coho that returned to Merwin trap in 2018 were of natural origin. This proportion is similar to years 2014 (11.2%) and 2015 (6.5%), and lower than 2016 (34.5%) and 2017 (54.4%). A number of PIT tagged adults returned to Merwin Trap in 2018, after being tagged at Swift FSC in previous years.

A total of 4,912 late coho, 2,148 early coho, 1,225 blank wire tag winter steelhead, 700 spring chinook, and 77 cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program in 2018 (Table 4.1-2). Of the 4,914 late coho that were transported upstream, 538 were collected at the Merwin Trap and 4,376 were collected at Lewis River Hatchery. Of the 2,148 early coho that were transported upstream, 1,053 were collected at the Merwin Trap and 1,095 were collected at Lewis River Hatchery. Of the 700 Spring chinook that were transported upstream in 2018, 329 were collected at Merwin Trap, and 371 were collected at Lewis River Hatchery. All wild early coho collected at both locations were transported upstream. Wild origin late coho were transported upstream only after meeting brood incorporation goals. All wild winter steelhead and Cutthroat that were transported upstream were collected at the Merwin Trap. All transported winter steelhead were blank wire tag fish; no true wild winter steelhead were transported upstream.

Table 4.1-1. Total fish collected at Merwin Trap during 2018. Resident rainbow trout and cutthroat were not gender-typed.

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]	949	736	50	173	159	15	16	7	1									**2106**	13.7
Fall Chinook	144	128	7	13	10	4	108	98	111									**623**	4.1
Early Coho	417	385	1150	107	111	220	79	79	314									**2,862**	18.7
Late Coho	378	335	165	46	54	33	129	121	82									**1,343**	8.8
Summer Steelhead	1425	2337					5	14			1				554	1231		**5,567**	36.3
Winter Steelhead	490	798					47	73		5	8		683	534	47	37		**2,722**	17.8
Sockeye Salmon							12	11		1	4							**27**	0.2
Chum Salmon																		**0**	0
Pink Salmon																		**0**	0
Cutthroat (>13 inches)																	78	**78**	0.5
Cutthroat (< 13 inches)																		**0**	0
Rainbow (< 20 inches)																		**0**	0
Bull Trout (> 13 inches)																		**0**	0
Bull Trout (< 13 inches)																		**0**	0
															Total			**15,328**	100

[a] Counts of male and female spring Chinook may vary slightly from those reported by WDFW broodstock counts.

Table 4.1-2. Total fish transported above Swift Dam in 2018.

Species	Male	Female	Jack	Not sexed	Female:Male Ratio	Jack:Adult Ratio	Total
Spring Chinook	491	177	32	-	0.34	0.05	***700***
Early Coho	1,173	662	313	-	0.47	0.18	***2,148***
Late Coho	2,826	1997	89	-	0.69	0.02	***4,912***
Winter Steelhead	685	540	-	-	0.79	-	***1,225***
Cutthroat >13"	-	-	-	77	-	-	***77***
Bull Trout >13"	-	-	-	-	-	-	***0***
						Total	***9,062***

4.2 Adult Passage Survival

4.2.1 Overview

Section 9.2.1(h) of the Settlement Agreement requires 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:

$$UPS = 1 - \frac{AD_{TRAP} + AD_{REL}}{N}$$ **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 9,062 adult salmonids (2,079 early coho, 4,912 late coho, 1,225 winter steelhead, 700 Spring Chinook, and 77 cutthroat) were transported upstream throughout the migration period in 2018. All cutthroat trout and winter steelhead survived the trapping and transport processes resulting in a UPS of 100 percent. Both early and late coho exhibited UPS rates of 99.8%. Spring Chinook demonstrated the lowest UPS of all species in 2018, at 98.4%. The majority (66.7%) of mortalities observed in 2018 occurred during the trapping process (10 spring Chinook, 3 early coho, and 3 late coho). The remaining 33.3% occurring during transport (6 late coho, 1 early coho, and 1 spring Chinook). A total of 24 mortalities were observed across all species, resulting in a UPS of 99.7 percent (Table 4.2-1).

Table 4.2-1. Overall upstream passage survival for Merwin Trap in 2018.

Species	Number Transported	Trap Mortalities	Transport Mortalities	Upstream Passage Survival (%)
Early Coho	2,079	3	1	99.8
Late Coho	4,912	3	6	99.8
Spring Chinook	700	10	1	98.4
Winter Steelhead	1,225	0	0	100
Coastal Cutthroat	77	0	0	100
Total	**9,062**	**16**	**8**	**99.7**

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.*

The M&E Plan defines a performance standard of 98% collection efficiency, or ATE, for fish that enter the Merwin Dam tailrace.

Following 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 at locating the trap entrance, but lower rates of fish being successfully captured by the fish crowder and lift assembly.

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.

Results from both 2015 and 2016 (Stevens et al. 2016; Caldwell et al. 2017) indicated a relatively high success rate for tagged fish at locating the trap entrance, but lower rates of fish being successfully captured. This indicated fish were exiting the trap before they were collected. Moreover, based on both (1) initial ARIS camera data and (2) operational scenario modeling of network analysis output, it appeared that (A) fish passage was constrained at the hopper, and that (B) the frequency of fish crowder operation strongly affected the 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. One outcome that was informed by these findings was the installation, in November 2016, of a single V-style fyke to prevent fish from returning to the tailrace once they have entered the trap. In addition, increased frequency of hopper operation was implemented to improve ATE in 2017.

Similar to the observations made in 2015 and 2016, results of the 2017 evaluations (winter steelhead and coho salmon) also indicated a relatively high success rate for tagged fish locating the trap entrance (P_{EE}), but slightly lower rates of fish being successfully captured. However, the discrepancy between these two metrics was significantly lower in 2017 than in previous years for both winter steelhead and coho salmon. This difference was directly correlated to the presence of the fyke in Pool 2, which prevented fish from returning to the tailrace once they had entered the trap. Although collection efficiency increased for both species in 2017, it was still below the performance standard of 98 percent. Cross-year comparisons using three years of data on winter steelhead (2015-2017) were made in 2017 to better understand how operational conditions (e.g., overall discharge from Merwin Dam, discharge from power generating turbines) might influence observed ATE_{test}. Based on these comparisons, there was limited evidence to suggest an effect of discharge from a power generating turbine in front of the trap entrance on trap entrance itself. However, there was some evidence that once overall discharge from Merwin Dam increased above 8,000 cfs, fewer fish reached the area outside the trap entrance or entered the trap. The results of this study also suggest there may be negative bias in estimating ATE_{test} using the current study design associated with: 1) using trap non-naïve test fish; 2) using hatchery origin fish rather than fish from the upper basin; and 3) not accounting for natural straying rates and fish condition. These possible factors were evaluated in 2018.

The primary goal of the 2018 Merwin ATE study was to continue to evaluate the performance of the Merwin Trap using radio telemetry. In particular, this study was designed to assess whether passage metrics differ between test fish that are captured and tagged downstream of the trap (trap-naïve fish) and those that are collected after passing through the trap once, tagged and released back downstream (trap non-naïve fish). The focus of the 2018 effort was on winter steelhead and coho salmon because it was anticipated that low numbers of spring Chinook would be returning to the Lewis River in 2018.

4.3.1 Results/Discussion

A detailed report of the fouth year of data collection (2018) for winter steelhead is provided in Appendix B and the third year of data collection on coho salmon is provided in Appendix C.

Adult Winter Steelhead

Consistent with previous years, during the 2018 study year, all tagged (both trap non-naïve and trap-naïve) winter steelhead appeared to locate and enter the trap at a higher rate (P_{EE} of 99%) than the rate at which they were captured (i.e., ATE_{test} of 93%; Table 4.3-1). Another general insight from the 2018 study was that ATE_{test} and P_{EE} were the highest observed values during the four years of evaluating these metrics at Merwin Dam for all tagged winter steelhead. High observed ATE_{test} and P_{EE} in 2018 was likely related to fish being more attracted the tailrace and trap compared to previous study years. Evidence in support of this included:

1) Tagged winter steelhead generally had high transition rates moving forward towards the tailrace and trap from downstream locations;
2) Fewer winter steelhead were detected at the furthest two downstream sites from Merwin Dam;
3) None of the tagged steelhead were detected in neighboring tributaries suspected of attracting strays;
4) Once tagged steelhead entered the tailrace in 2018, the path most frequently used by fish was along the south side of the tailrace where the trap entrance is located; and
5) 99% of tagged fish that entered the tailrace located the trap entrance.

Concerning trap non-naïve verses trap naïve winter steelhead, results from the 2018 study indicated that:

1) ATE_{test} was higher for trap naïve winter steelhead compared to trap non-naïve fish (100% of trap naïve fish that entered the tailrace were trapped compared to 93% of trap non-naïve fish - Table 4.3-1);
2) Despite being released further downstream from the dam tailrace than trap non-naïve fish, trap naïve fish visited significantly fewer sites (31 fewer sites on average) before being recaptured compared to trap non-naïve fish, suggesting less exploratory behavior or milling and more directional homing in the lower river by naïve fish;
3) Trap naïve fish generally had higher probabilities of moving forward from sites within the tailrace and trap, as well as at sites immediately downstream of the tailrace, again suggesting less milling;
4) Zero trap naïve fish left the tailrace after entering, and zero trap naïve fish left the trap after entering. In contrast, 54% of the trap non-naïve fish left the tailrace after entering, and 50% of the trap non-naïve fish left the trap after entering;
5) Trap naïve fish had significantly lower residence times (19 hours less on average) in the tailrace compared to trap non-naïve fish.

Overall, results comparing trap trap naïve and trap non-naïve winter steelhead indicate trap naïve fish exhibited more directed movements towards the tailrace and trap after release compared to trap non-naïve fish, which could be associated with the higher observed trapping rate for trap naïve fish (Table 4.3-1). While tagged fish that had not been previously trapped performed better and had higher observed trapping rates compared to fish that had been previously trapped, it was suggested that low sample sizes of the former may have limited the ability to detected statistical differences in passage efficiency. It was also suggested that core passage metrics and movements of trap naïve and non-naïve fish continue to be monitored. Effort in 2019 will continue to monitor these potential differences in winter steelhead.

Adult Coho Salmon

Simlar to winter steelhead and consistent with previous years, all radio tagged adult coho in 2018 appeared to locate and enter the trap at a higher rate (P_{EE} of 73%) than the rate at which they were captured (P_{CE} of 68%; Table 4.3-1). However, due to low run size of adult coho return to the Lewis River in 2018, sample sizes were not met and statistical camparison was limited. In addition, most of the tagged fish used in this study were of hatchery origin (HOR; 70/78 or 90%) rather than natural origin (NOR) as was the original intent. As a result, the majority of tagged fish were not attacted to the Merwin Dam, but rather the Lewis River Hatchery located further downsteream. It was recommended that HOR coho not be used for furture studies to evaluate the fish trap at Merwin Dam.

Key results from the 2018 study pertaining to the core passage metrics for adult coho salmon include the following:

1) A total of 78 Coho salmon (combined trap non-naïve and trap naïve) were tagged between 21 September – 29 October;
2) 77 Coho salmon were detected in the study array in the North Fork Lewis River;
3) Only 25 Coho salmon subsequently entered the tailrace of Merwin Dam following release (composing the group of fish that were included in estimates of core metrics);
4) Of the 25 coho salmon that entered the tailrace 20 entered the trap, for an overall P_{EE} of 73%;
5) Of the 20 coho salmon that eneted the trap, 17 were successfully recaptured, for a combined P_{CE} of 68% (spanning 48-83%, which was below the 98% *ATE* performance standard);
6) Comparisons of P_{CE} to the 98% performance standard indicated there was less than a 0.0001% probability that the true *ATE* of the combined parent population met or exceeded the target.
    - Note: there was no statistical analysis using trap naïve coho salmon alone in 2018 due to low samples sizes of trap naïve coho salmon that entered the tailrace (*n*=2).
7) Median tailrace residence time was 3.5 hours, which was below the maximum the performance standard of less than 24 hours. However, 6% of fish exhibited tailrace residence times greater than 168 hours, which marginally exceeds the performance standard of less than 5% of fish residing within the tailrace greater than 168 hour; and
8) The use of HOR coho salmon for evaluating passage at the Merwin Dam fish trap is potentially inappropriate, and that NOR coho salmon from the upper basin are a better alternative.

Table 4.3-1. Summary of passage metrics for tagged fish released into the tailrace of Merwin Dam in 2018.

Metric	Coho Salmon	Spring Chinook	Steelhead
Total Tagged (n)	78	NA	92
Trap Non-Naïve	*63*	*NA*	*73*
Trap Naïve	*15*	*NA*	*19*
Entered the Tailrace	25	NA	83
Trap Non-Naïve	23	*NA*	*67*
Trap Naïve	2	*NA*	*16*
Entered the Trap	20	NA	82
Trap Non-Naïve	19	*NA*	*66*
Trap Naïve	1	*NA*	*16*
Trap Entrance Efficiency (P_{EE})	73%(61-91%)	NA	99% (94-100%)
Trap Non-Naïve	*75% (63-92%)*	*NA*	*99% (92-100%)*
Trap Naïve	*50% (NA)*	*NA*	*100% (80-100%)*
Captured	17	NA	77
Trap Non-Naïve	16	NA	*61*
Trap Naïve	1	NA	*16*
Collection Efficacy (P_{CE})	68% (48-83%)	NA	93% (85-97%)
Trap Non-Naïve	*70% (49-84%)*	*NA*	*91% (83-96%)*
Trap Naïve	*50% (NA)*	*NA*	*100% (84-100%)*

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 and spring Chinook, comprehensive spawning ground surveys were conducted in the potentially accessible river and stream reaches upstream of Swift Dam in 2018. 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.

4.4.2 Results/Discussion

Data collection on the spawn timing, distribution, and abundance of transported spring Chinook and coho was completed the end of December, 2018. The reports summarizing these data are provided in Appendix D. Data entry, QA/QC, summary and analysis is still ongoing for ariel flight data for winter steelhead. When complete, the results will be attached as an Appendix to this report. No ground surveys were completed for winter steelhead in 2018 due to poor road conditions and unacessablity of most of the upper basin due to snow pack.

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 (i.e., 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 recommended 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. Halfway 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 are outlined in the latest version of the M&E Plan **(**PacifiCorp and Cowlitz PUD 2016**)**. 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 PERFORMANCE 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-origin adult 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 (PacifiCorp 2016).

7.2 Results/Discussion

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

1) Used 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 fully operational.

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APPENDICES

APPENDIX A

LEWIS RIVER ACCLIMATION PROGRAM – RELEASE STRATEGY MEMO (JUNE 29, 2018)

MEMO
Lewis River Acclimation Program – Release Strategy Memo to the H&S Subgroup
Prepared by PacifiCorp

June 29, 2018

Introduction

The original spring Chinook acclimation program called for 100,000 juvenile spring Chinook salmon to be released at acclimation sites upstream of Swift Dam. Due to poor performance of the acclimation facilities combined with substantial damage sustained during recent high water events, all sites are in the process of being decommissioned. The primary purpose of acclimating spring Chinook juveniles to the upper basin above Swift Dam was to promote the distribution of returning adults spawners throughout the available spawning habitat upstream of Swift Dam. As naïve spring Chinook adults transported above Swift Dam in 2017 spawned widely across the available habitat (throughout the upper Lewis River, Muddy River watershed, and Swift Reservoir tributaries), it appears that acclimation of juvenile spring Chinook may not be necessary to accomplish this primary acclimation goal. Therefore the ACC H&S Subgroup recommended releasing the 100,000 juvenile spring Chinook salmon (formerly allocated for the upper basin acclimation sites) downstream of Merwin Dam in 2018 and into the near future. The purpose of this draft memorandum is to briefly describe potential approaches for the spring Chinook supplementation program over the next 5 years (2019 – 2024) and provide a starting point for discussion at the May 31, 2018 H&S Subgroup meeting. It is intended that the subgroup will make a final discussion at the meeting regarding the reallocation of the upper basin juvenile spring Chinook acclimation fish to being released below Merwin Dam, evaluation of juvenile release and tagging strategy, and ongoing monitoring programs for adult spawning distribution and juvenile production.

Proposed 2018 Release Strategy

The 100,000 juvenile spring Chinook currently being held at Speelyai Hatchery for 2018 release have not been tagged and still have adipose-fins intact. The original intent was for these fish to be direct-released throughout the upper basin in July and August 2018. The target size for fish at release was set at approximately 52 fish to the pound.

Given their projected size this fall, two potential release strategies for the 2018 fish release include: 1) incorporating them into the October release already developed and outlined in the 2018 Hatchery and Supplementation Program Annual Operating Plan (AOP); or 2) releasing them independently this fall and in parallel with the observed out-migration period for spring Chinook captured upstream of Swift Dam (which generally peaks in late-November). For the first strategy, the 100,000 fish would be transported to Lewis River Hatchery and incorporated into the October release group. For releasing fish independently, the proposed release strategy consists of releasing approximately 25,000 smolts per week to the Woodland Release Ponds. The capacity of the release ponds is approximately 76,000 fish of the expected size range of spring Chinook juveniles to be released. As each batch of 25,000 smolts are released to the release ponds, they would be able to volitionally migrate out of the ponds to the North Fork Lewis River for a 6 day period. On the 7th day, they would be force released, and the new batch of 25,000 smolts would be transport from Speelyai Hatchery and added to the ponds, continuing with the 1 week volitional then force release strategy for each group. The first release would occur the first week in November. All fish would be released by the first week of December. Under the original acclimation program (i.e. releasing the 100,000 spring Chinook upstream of Swift Dam), approximately 15% (15,000) of these fish would have received a PIT Tag to be later detected at the Swift Reservoir Floating Surface Collector to assess acclimation pond success. Because these fish will now be released below Merwin Dam, it will need to be decided whether a similar proportion of these fish will still need to be tagged and what purpose that information will serve. As returning adults, these fish would not be available to angler harvest, thus increasing the number of potential adults available for transport upstream of Swift Dam to spawn.

Proposed 2019 – 2024 Marking and Release Strategy

Option 1: Full Integration into Existing Hatchery Program (Adipose Clipped)

Under this option, the 100,000 spring Chinook, formerly allocated to the acclimation program above Swift Dam, would be completely integrated into the overall spring Chinook hatchery program releases downstream of Merwin Dam, increasing the total program production from 1.25 million to 1.35 million fish. This would remain a segregated program; any NOR adult spring Chinook that return to spawn over the next five years would be taken upstream and not used for brood stock.   Marking and monitoring of the total program fish would follow the strategy outlined in the Hatchery and Supplementation Program Annual Operating Plan (AOP). The monitoring and evaluation strategy in the AOP will eventually determine the release strategy with the best survival results. This strategy minimizes logistical hurdles of segregating the 100,000 spring Chinook at the hatchery and separately marking them from other program fish releases. As some of the total program fish are adipose fin clipped and available for harvest, there would be some increased harvest of the adults produced by the addition of the 100,000 juveniles to the total program release (compared to if these fish were not marked as under the existing acclimation program or proposed 2018 release). However, the addition of these fish to the overall hatchery releases should provide additional returns to support broodstock and adult supplementation targets.

Option 2: Full Integration into Existing Hatchery Program (Adipose Intact)

Under this Option, 100,000 spring Chinook would not be adipose clipped, but releases would still be spread over the same time period as the general program releases (until monitoring under the AOP identifies the optimal release strategy). Not marking these fish would be consistent with the acclimation program strategy in that Option 2 would minimize angler harvest of the adult returns from these 100,000 fish further increasing adults available for upstream adult supplementation. Under Option 2, the program would also remain segregated; any NOR adult spring Chinook that return to spawn over the next five years would be taken upstream and not used for brood stock.

Option 3: Separated from Existing Hatchery Program (Adipose Intact yet Differentially Marked)

Under this option, a portion of the returning NOR adults would be used as parental stock to produce 100,000 spring Chinook smolts (similar to the original acclimation program), which would then be released below Merwin Dam. The 100,000 smolts would be differentially marked from other program fish so as to not be available to angler harvest and so that they could be specifically identified for transport as adults to spawn upstream of Swift Dam. This would entail segregation in the hatchery and application of a differential external mark from other program fish causing logistical constraints. As CWT and adipose fin clip combinations are already allocated to other program fish, a different external visual mark would be required. Previous studies have shown some decreased survival (below the survival observed for adipose clip/CWT marked fish) for various salmonid species using other marks, such as ventral or pectoral fin clips, and maxillary clips (Jones and Bottomley 1997); however, Jones and Bottomley (1997) and Olson and Cates (undated) failed to detect a difference in survival between fin clip mark types in spring Chinook, though low sample size and low overall adults survival was acknowledge in both studies. Conservatively, it should be assumed that some decreased smolt to adult survival may occur under Option 3 compared to Option 1 and Option 2, by using a fin clip or maxillary clip, other than the adipose fin. However, adult returns of these (supplementation) fish could be differentiated as HOR from other unclipped (NOR) returns.

Monitoring and Adaptive Management

Ongoing Adult Spawning Distribution and Juvenile Production Monitoring

The spawn timing, distribution, and abundance of transported adult spring Chinook upstream of Swift Dam will continue to be monitored as described in Objective 15 of the current the Monitoring and Evaluation Plan for the Lewis River (as has been done since 2012 for transported anadromous fish). Juvenile spring Chinook production resulting from the spawning of these transported adult spring Chinook will continue to be evaluated by operating the screw trap at Eagle Cliff and collection at the Swift Floating Surface Collector as described in Objectives 6, 7 and 8 of the current Monitoring and Evaluation Plan for the Lewis River.

Adaptive Management

If annual spawning surveys (Objective 15) show that transported spring Chinook are not distributing throughout the available spawning habitat upstream of Swift Dam, contrary to the 2017 spawning survey results, then an acclimation release strategy for the 100,000 juvenile spring Chinook to the basin upstream of Swift Dam will be re-visited by the H&S subgroup as part of annual planning.

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APPENDIX B

MERWIN ADULT TRAP EFFICIENCY EVALUATION (WINTER STEELHEAD) – 2018 REPORT

Responses to Comments Received on 2018 Draft Merwin Upstream Passage Adult Trap Efficiency - Winter Steelhead

	Commenter	Comment Number	Location	Comment	Response
1	Joshua Ashline, NMFS	1	Page 20 Figure 6	Why are there fewer unique tag codes at ENT and Pool 4 vs pool 2, hopper, and trap? The Pee metric is calculated to identify the ability of fish to find and enter the trap, and it seems the ENT antenna site doesn't operate as well as others. Especially with more unique tags identified in pool 2 and the hopper.	PacifiCorp appreciates the ACC's observation that fewer fish were detected at the ENT and PL4 sites, and this is something that the researchers considered during the study and analysis. Fewer unique tag codes detected at the ENT and Pool 4 suggest fish passed these receivers without being detected. This could occur for a few reasons. One reason would be that these receivers were not sensitive enough to detect the tagged fish. This is unlikely for the ENT site given testing is performed on receivers prior to and during the study, and in addition, a beacon tag is detected at regular intervals at the site to ensure the receiver is not missing detections. The PL4 site undergoes similar testing prior to the study but does not have a beacon tag present at the site due to its location within the trap ladder being difficult to access. Thus, the PL4 site is more likely to have missed detections due to a receiver sensitivity issue, but data over the course of the study did not indicate this. A more likely explanation is that these locations are areas where fish did not spend enough time for tags to be detected. For example, the ENT site has extremely high flows and no holding area for fish. Thus, fish must quickly pass this area, which increases the chance that radio tag signals go undetected (radio tags emit signals at fixed intervals and receivers must detect the full signal sequence to register a detection).The Pee metric defines a fish has entered the trap when it is detected at the ENT site OR any site further upstream. There are no fish that are detected at the ENT site and not further upstream indicating all fish that pass the ENT site are subsequently detected further upstream. This makes sense because the ENT sit has high flows so fish must pass through quickly to effectively enter the trap. Overall, PL2 and the HOP site have high detection efficiency and thus, we are highly confident that our radio receivers detect fish that enter the trap and that Pee metric accurately identifies the ability of fish to enter the trap from the tailrace. To address this comment within the report, we included additional text on page 20 (see the third bullet point), as well as in the Methods on page 14 when describing how Pee is calculated.
2	Joshua Ashline, NMFS	2	Page 28, number 6	As we discussed today I would like to see the higher (further up) and lower (downstream) probabilities moving forward.	PacifiCorp agrees with this comment.
3	Joshua Ashline, NMFS	3	Page 38, Figure 15	Again its evident something is off with the antennas in Ent and PL4, I think the report would benefit from a short description of why there's fewer detections at these locations compared to PL2 which is located between ENT and PL4.	See response to comment #1 above. In addition, this figure indicates fish were spending most of their time holding in PL2, PL4, and near the HOP sites based on high median residence times at the these sites. This supports the idea that fish were not holding at the ENT site, thus fewer fish were detected at this site, a finding consistent with previous years data. The fewer number of site visits to PL4 but high median holding time suggests that most fish did not hold in PL4 (i.e., they passed the site and held at PL2), but the fish that did hold at the PL4 site did so for similar amounts of time compared to fish at the PL2 and HOP site. Overall, the PL4 and ENT site did miss detections of fish that passed, however, this does not influence our conclusions about trap entrance behavior (e.g., Pee) due to high detection efficiency of fish at other sites in the trap ladder. To address this comment within the report, we included additional text on page 37 (see the #3 observation).
4	Joshua Ashline, NMFS	4	Page 48, Figure 20	The energetic state of fish should be monitored with all ATE studies, and continue into the future. This is an important variable, as adjustments are made to the Merwin upstream collector, as we are insuring that the upstream collector is inclusive to the diversity of energetic states of fish reaching the collector.	PacifiCorp agrees with this comment. Lipid content will continue to be monitiored for test fish used in future studies.
5	Joshua Ashline, NMFS	5	Page 56, Paragraph 1	Several potential reason are discussed for a decreasing ATEtest with respect to lower energy reserves. Including higher temp gonadal development ect. I also believe a potential explanation for the decrease in ATEtest could be tha the energetic cost of navigating the Merwin trap is too great for fish with diminished energy reserves. Lipid content ATE tagged fish should continue, to discern if this is a plausible explanation for reduced ATEtest.	See response to comment #4 above. PacifiCorp agrees that lipid content should be continued to be monitiored for test fish used in future studies.
6	Joshua Ashline, NMFS	6		I believe all fish tagging data, and summarized telemetry data should be released within the appendix of these reports.	A table (Appendix A-3) was inserted in the appendix that summarizes fish data and detection data for individual fish. This table was referenced on pg 19 of the report.

MERWIN UPSTREAM PASSAGE ADULT TRAP EFFICIENCY – WINTER STEELHEAD

2018 Final Annual Report

Prepared for:

PacifiCorp
825 NE Multnomah St.
Portland, OR 97232

Prepared by:

Matt Drenner, Kai Ross, Lindsey Belcher, Mark Morasch, Elizabeth Schotman, Andrew Muller, and Lucius Caldwell

Cramer Fish Sciences; Portland, OR

December 19, 2018

EXECUTIVE SUMMARY

This report describes results from the fourth 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. This report focuses on results evaluating collection efficiency of blank wire tag (BWT) hatchery Winter Steelhead.

The M&E Plan defines a performance standard of 98% collection efficiency, or Adult Trap Efficiency (*ATE)*, for fish that enter the Merwin Dam tailrace. Overall population *ATE* is estimated from a tagged group of study fish, for which ATE_{test} is calculated. Aside from ATE_{test}, two additional core metrics are presented for evaluating Merwin Dam trap effectiveness. Trap entrance efficiency (P_{EE}) quantifies the proportion of fish entering the Merwin Dam tailrace that subsequently entered the trap, regardless of whether they were eventually captured or exited the trap and returned downstream. P_{EE} indicates the ability of study fish to locate and enter the trap from the tailrace. We also report trap ineffectiveness (T_i), which is the difference between P_{EE} and ATE_{test}. Evaluation of T_i can reveal an operational or infrastructural weak link in upstream passage at the trapping device—a failure to capture fish once they have entered the trap rather than a failure to attract fish to the trap entrance.

The objectives of the 2018 Merwin *ATE* evaluation were as follows:

1) Determine ATE_{test} for 2018 and compare this value to the performance standard of 98%.
2) Evaluate directional movement of fish in the tailrace, trap, and downstream.
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., energetic state, stress levels and injury rates).
7) Monitor environmental factors (e.g., discharge) that could influence recapture rates.

To evaluate core passage metrics and behaviors, all previous study years used fish collected from the Merwin Dam fish trap that were tagged with radio tags and released immediately downstream of Merwin Dam. Thus, all fish had been previously trapped (i.e., they were Non-Naïve to the trap) and core passage metrics were estimated from fish making second attempts to locate and enter the trap. It was proposed that estimates of core passage metrics could be biased if fish were less likely (or less able) to locate and enter the Merwin Dam fish trap a second time.

Thus, in 2018, core passage metrics and movements were evaluated for a group of trap Naïve fish, and comparisons were made between the two release groups of Steelhead:

- Fish captured at the Merwin Fish Collection Facility and subsequently released downstream (i.e., trap Non-Naïve fish);
- Fish captured, tagged and released downstream from Merwin Dam, and thus presumably had no prior encounter with the trap (i.e., trap Naïve fish).

After release, radio telemetry was used to assess collection efficiency and infer movements of tagged fish at locations within Merwin Dam tailrace, Merwin Dam fish trap ladder, and at sites downstream of Merwin Dam in the Lewis River.

Core passage metrics from 2015-18 are summarized in Table 1, below. Notably, estimates of ATE_{test} and P_{EE} for Winter Steelhead in 2018 were the highest across all species and study years examined.

Table 1. 2018 values for P_{EE}, ATE_{test}, and T_i. Sample sizes (N) reflect the total number of tagged fish that were released in each study year. Note that to estimate 95% confidence intervals (CI), 2018 used Bayesian Credible Intervals, whereas all other study years used bias-corrected and accelerated methods.

Study Year	***Species/release group***	***N***	***P_{EE} (95% CI)***	***ATE_{test} (95% CI)***	***T_i***
2015	Winter Steelhead	148	86% (79-90%)	61% (51-67%)	29%
	Spring Chinook	40	90%	38%	58%
	Coho Salmon	35	23% (12-40%)	9% (4-28%)	61%
2016	Winter Steelhead	148	93% (87-96%)	73% (65-80%)	21%
	Spring Chinook	*N/A*	*N/A*	*N/A*	*N/A*
	Coho salmon	*N/A*	*N/A*	*N/A*	*N/A*
2017	Winter Steelhead	150	84% (77-90%)	76% (70-84%)	9%
	Spring Chinook	*N/A*	*N/A*	*N/A*	*N/A*
	Coho Salmon	149	70% (60-83%)	63% (50-74%)	10%
2018	Winter Steelhead	92	99% (94-100%)	93% (85-97%)	6%
	Non-Naïve	73	99% (92-100%)	91% (83-96%)	8%
	Naïve	19	100% (80-100%)	100% (84–100%)	0%

Key results from the 2018 study pertaining to the core passage metrics for Steelhead include the following:

- A total of 92 BWT Winter Steelhead (combined Non-Naïve and Naïve) were tagged between February 22nd and April 24th.
- All 92 Steelhead were detected in the study array in the North Fork Lewis River.
- 83 Steelhead subsequently entered the tailrace of Merwin Dam following release (composing the group of fish that were included in estimates of core metrics)
- 82 Steelhead entered the trap, for an overall P_{EE} of 99% (82/83)
    - P_{EE} in 2018 (99%) was 6 percentage points greater than the next highest P_{EE} across all study years (P_{EE} for Steelhead in 2016 was 93%)
- 77 Steelhead were successfully recaptured, for a combined ATE_{test} of 93% (77/83)
    - ATE_{test} in 2018 (93%) is 17 percentage points greater than the next highest ATE_{test} across all study years (ATE_{test} for Steelhead in 2017 was 76%).
    - 95% confidence intervals for ATE_{test} in 2018 spanned 85-97%, which is below the 98% *ATE* performance standard.
- Comparisons of ATE_{test} to the 98% performance standard indicated there was less than a 0.2% probability that the true *ATE* of the combined parent population met or exceeded the target.
    - Of note, using data for Naïve fish alone, analysis indicated there was a 29% probability that the true *ATE* of the parent population met or exceeded the target.

We also compared the amount of time that fish were present in the tailrace to performance standards. Median tailrace residence time was 14 hours, which is below the maximum (i.e., achieves) the performance standard of median tailrace residence time less than 24 hours. In addition, only 4% of fish exhibited tailrace residence times greater than 168 hours, which is below the maximum (i.e., achieves) the performance standard of less than 5% of fish residing within the tailrace for this long. Thus, performance standards for median tailrace time of less than or equal to 24 hours with less than 5% of fish taking longer than 168 hours to pass were both met for Winter Steelhead (combined Non-Naïve and Naïve) in 2018.

Consistent with previous years, during the 2018 study year, all tagged (both trap Non-Naïve and Naïve) Winter Steelhead appeared to locate and enter the trap at a higher rate (P_{EE} of 99%) than the rate at which they were captured (i.e., ATE_{test} of 93%). This observation is reflected by a trap ineffectiveness (T_i) of 6% for 2018, which is similar to T_i in 2017 (9%). T_i in 2017-18 was lower than during 2015-16 (21-18%), which is likely a result of the addition of a fyke to the trap prior to 2017 studies. However, 50% of Steelhead that entered the trap exited the trap in 2018 (most of these were eventually recaptured, hence why T_i was only 6%), which was twice the proportion of fish that exited the trap in 2017, the first year the fyke was present. We hypothesize that differences in trap retention between years is associated with Lewis River discharge: when Lewis River discharge is low, higher flows through the trap ladder may provide fish with a directional cue to locate the exit point through the fyke. Regardless of the mechanism behind trap exit events, if all fish that entered the trap were successfully trapped in 2018, the performance standard of 98% *ATE* would have been achieved.

A key insight from the current year study was that ATE_{test} and P_{EE} for 2018 Winter Steelhead were the highest observed values during the four years of evaluating these metrics at Merwin Dam. High observed ATE_{test} and P_{EE} in 2018 is likely related to Steelhead being more attracted the tailrace and trap compared to previous study years. Evidence in support of this includes:

- Steelhead generally had high transition rates moving forward towards the tailrace and trap from downstream locations.
- Few Steelhead were detected at the furthest two downstream sites from Merwin Dam.
- None of the Steelhead were detected in neighboring tributaries suspected of attracting strays.
- Once Steelhead entered the tailrace in 2018, the path most frequently used by fish was along the South side of the tailrace where the trap entrance is located.
- 99% of fish that entered the tailrace located the trap entrance.

Other variables that could be associated with high ATE_{test} and P_{EE} in 2018 include operational changes (e.g., the presence of a fyke in the trap ladder), environmental conditions (Lewis River discharge), or internal fish factors (e.g., physiological or energetic state). Results from 2018 indicated stress levels of fish at the time of release were low, and therefore unlikely to influence post-release behavior. However, body fatmeter readings indicated that fish with lower energy reserves were less likely to be trapped. Energetic state is an emergent indicator of the background condition of fish (i.e., the condition of fish based on factors encountered in previous life stages) and is not under control of PacifiCorp.

Additional important findings from the current year related to the comparison between trap Naïve and trap Non-Naïve fish. Results from the 2018 study that indicated, among other things, the following key differences between Naïve fish and Non-Naïve fish:

- ATE_{test} was higher for Naïve fish compared to Non-Naïve fish.
    - 100% of Naïve fish that entered the tailrace were trapped compared to 93% of Non-Naïve fish.
    - There was an 80% probability that ATE_{test} was 5% greater for Naïve fish than for Non-Naïve fish.
- Despite being released further downstream from the dam tailrace than Non-Naïve fish, Naïve fish visited significantly fewer sites (31 fewer sites on average) before being recaptured compared to Non-Naïve fish, suggesting less exploratory behavior or milling and more directional homing in the lower river by Naïve fish.
- Naïve fish generally had higher probabilities of moving forward from sites within the tailrace and trap, as well as at sites immediately downstream of the tailrace, again suggesting less milling.
- Zero Naïve fish left the tailrace after entering, and zero Naïve fish left the trap after entering. In contrast, 54% of Non-Naïve fish left the tailrace after entering and 50% of the Non-Naïve fish left the trap after entering.
- Naïve fish had significantly lower residence times (19 hours less on average) in the tailrace compared to Non-Naïve fish.

Overall, results comparing trap Naïve and Non-Naïve fish indicate Naïve fish exhibited more directed movements towards the tailrace and trap after release compared to Non-Naïve fish, which could be associated with the higher observed trapping rate for Naïve fish. Trapping and transportation experienced by Non-Naïve fish could cause delayed physiological perturbations and limit the performance of these fish during second passage attempts.

In conclusion, we are relatively confident that performance standards for adult collection efficiency at Merwin Dam were not met in 2018, but performance standards for the amount of time spent in the tailrace prior to passage were met. In addition, fish that had not been previously trapped performed better and had higher observed trapping rates compared to fish that had been previously trapped, but low sample sizes of the former may have limited the ability to detected statistical differences in passage efficiency. We suggest continuing to evaluate and compare core passage metrics and movements of trap Naïve and Non-Naïve fish, in addition to monitoring how NF Lewis River discharge influences trap retention.

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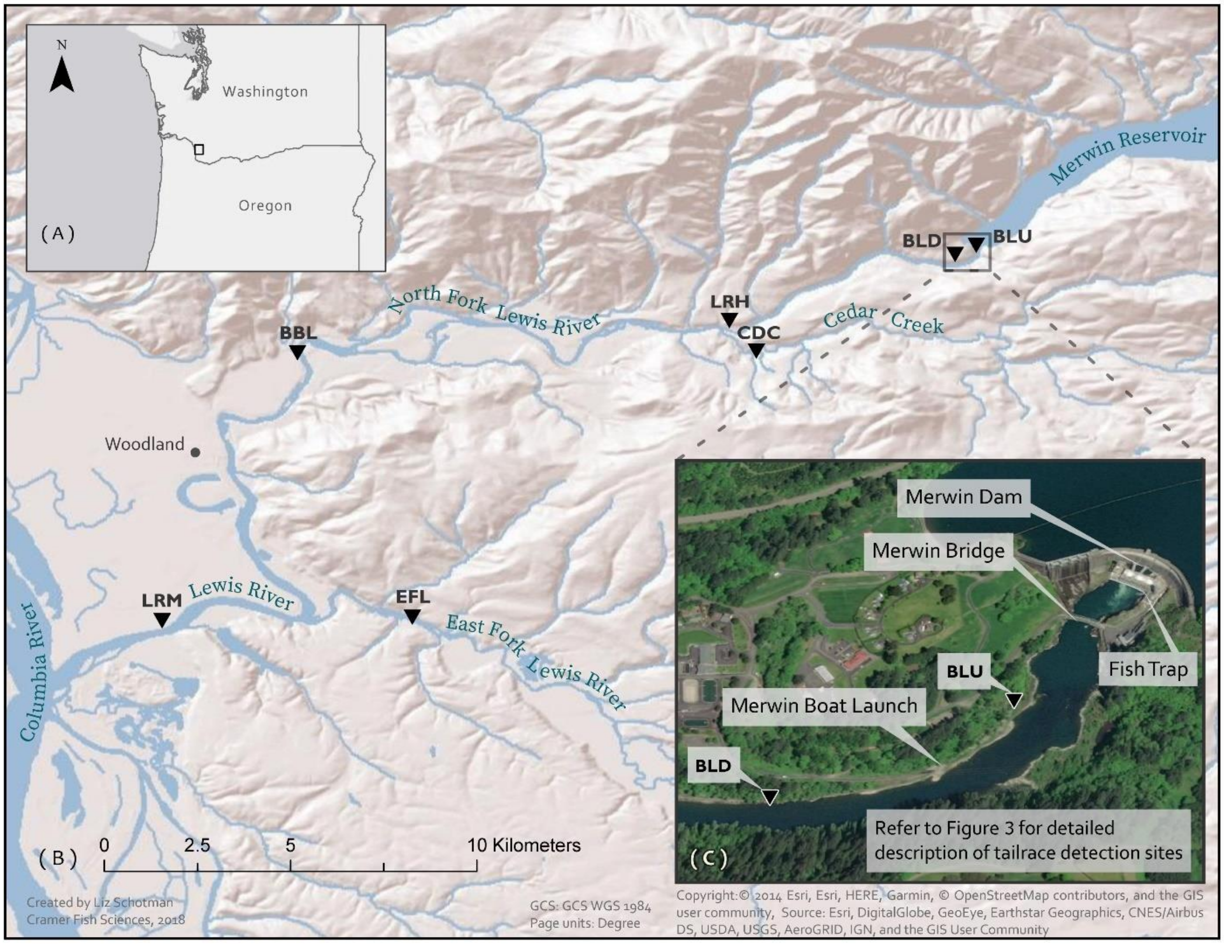
INTRODUCTION

Study Area

The Lewis River is a major tributary of the Columbia River, approximately 140 river km (RKM) (87 river miles, RM) upstream from the Pacific Ocean. The North Fork (NF) Lewis River hydroelectric project begins at Merwin Dam, located at RKM 31.4 (RM 19.5) of the NF Lewis River[1], and extends upstream through two other impoundments. This study is focused on the reach between Merwin Dam and confluence of the Lewis and Columbia Rivers, near Woodland, Washington (Figure 1). Our analyses for quantifying estimates of core passage metrics focus on fish that were detected within the Merwin Dam tailrace, defined as the area upstream of Merwin Bridge approximately 0.1 km downstream of Merwin Dam (Figure 1). Fish passage at Merwin Dam is facilitated via a fish trap located at the base of Merwin Dam on the South side (Figure 1).



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Cramer Fish Sciences, 2018

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Figure 1. Project area map indicating study region (A), extent of study within the Lewis River system (B), and study area and infrastructure near Merwin Dam (C). Black triangles indicate radio detection sites.

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[1] Throughout the remainder of this document, all river distances refer to Lewis River, i.e., distance upstream from Lewis River confluence with Columbia River

Study Background

The NF Lewis River Hydroelectric Project operates Merwin Dam under a Federal Energy Regulatory Commission license issued to PacifiCorp in June 2008. The license agreement stipulates requirements for reintroduction of salmonids and to provide both upstream and downstream passage of target salmonids (*Oncorhynchus* spp.) including spring Chinook Salmon (*O. tshawytscha*), Coho Salmon (*O. kisutch*), and Winter Steelhead *(O. mykiss*) [*for additional details about the licensing agreements see (PacifiCorp and Cowlitz PUD 2016)*].

Among objectives outlined in Phase 1 of the licensing agreement is the need to assess the effectiveness of passage facilities including evaluating adult trap efficiency (*ATE*) of the Merwin Fish Collection Facility. During the licensing process, it was agreed that *ATE* at Merwin Dam should meet or exceed a performance standard of 98% *ATE*. The use of radio telemetry was proposed to evaluate *ATE* because of the ability to actively monitor fish behavior in the tailrace of Merwin Dam.

Following updates to the Merwin Fish Collection Facility in 2014 and beginning in 2015, three years of radio telemetry studies have evaluated *ATE* and other biological metrics of adult salmonids at Merwin Dam and downstream in the NF Lewis River. Results from all three study years indicated the performance standard of 98% *ATE* was not being achieved (for additional details see Stevens et al. 2016, Caldwell et al. 2017, Drenner et al. 2018a, 2018b). Consequently, over the course of the study years, dam infrastructural and trap and dam operational adaptations have been undertaken to improve *ATE*, which has also resulted in improved understanding of the biological, operational, and environmental factors influencing *ATE*. For example, based on results from 2015 and 2016 study years, which showed relatively high rates of tagged fish entering the trap but lower rates of fish being successfully captured (Stevens et al. 2016 & Caldwell et al. 2017), a single V-style fyke was installed in the trap prior to 2017 studies to prevent fish from returning to the tailrace once they had entered the trap. Results from 2017 showed the fyke was effective in reducing the number of exit events from the trap but estimated *ATE* remained below the 98% performance standard (Drenner et al. 2018a, 2018b).

It was hypothesized that operational and environmental factors, such as flow through the power generating turbines and total background NF Lewis River discharge, may influence *ATE* at Merwin Dam. Exploratory comparisons of environmental and operational data between three study years provided weak evidence suggesting Winter Steelhead exhibited lower numbers of trap entrance attempts from the Merwin Dam tailrace during higher (> 8,000 cfs) total NF Lewis River discharge (Drenner et al. 2018). Additional years of data would increase confidence regarding inferences about the influence and effect size of environmental and operational factors on observed interannual differences in *ATE*.

Other biological factors were also identified that could contribute to below 98% passage efficiency at Merwin Dam, including fish straying into Lewis River tributaries (i.e., fish entering and potentially spawning in non-natal habitats) and fisheries removals. Importantly, the 98% performance standard for fish passage was originally derived from passage estimates at dams in the Columbia Basin and accounted for ‘drop-outs’ (e.g., strays, fisheries removals). Straying rates of salmonids in the Lewis River system are unknown, but evidence from fisheries captures and mortalities in neighboring tributaries suggests some level of straying within populations (personal communication with Chris Karchesky, PacifiCorp). The mechanism behind straying behaviors are poorly understood for salmonids, but are likely influenced by a combination of genetic, environmental, energetic and/or physiological (e.g., stress) factors (Keefer & Caudill 2014).

Consistent among study years, all fish included in *ATE* estimation analyses were first captured at the Merwin Fish Collection Facility, tagged and then released downstream of Merwin Dam (i.e., they must locate and enter the trap a second time). The use of previously trapped fish (or fish that successfully ascended a dam fishway) is common in fish passage studies because (1) it maximizes the likelihood that fish are volitionally targeting upstream spawning habitat, and (2) it is logistically easier to capture fish that are confined in a trap or narrow fishway than fish that are swimming freely in a large river. However, one explicit assumption of CFS's previous Merwin *ATE* studies (although frequently implicit or tacit within other studies) has been that recapture rates of previously trapped or passed fish accurately and appropriately reflect and equal rates of initial capture among the parent population of fish that never encountered a trap or fishway. Few studies have examined the effects of previous experience encountering a fish trap (or fishway) on subsequent passage rates, but in one study, Burnett et al. (2014) showed 16% lower passage rates of Sockeye Salmon captured from the top of a dam fishway compared to fish captured from below the dam. Reduced success rates during second passage attempts could be due to (A) high energetic costs incurred during first passage attempts, (B) aversive conditioning to the dam and trap resulting from prior trapping trauma, or (C) physiological stress imposed on fish from capture, handling, and transport. During project scoping for the current study, assessments of fish stress and energetic state prior to release downstream were suggested as means to provide insights into their role in behavior after release. Overall, until the effects of prior encounters with the trap are accounted for, previous estimates of *ATE* at Merwin Dam may have been biased low.

Study Objectives

The primary goal of this fourth study year was to continue to evaluate the performance of the Phase I trap location, design, and adequacy of attraction flow using radio telemetry. This study will also investigate, for the first time, whether passage metrics and behaviors differ between test fish that are captured and tagged downstream of the trap (i.e., trap Naïve fish) and those that are collected after passing through the trap once, tagged and released back downstream (i.e., trap Non-Naïve fish). This report focuses solely on results from evaluation of Winter Steelhead passage performance and behavior. A separate study for Coho Salmon in 2018 is underway, and that report will be forthcoming.

The specific objectives for the 2018 Steelhead evaluation included the following:

1) Determine *ATE* for Steelhead at Merwin Dam; compare estimates to the performance standard of 98%; and, compare passage metrics across study years.
2) Determine if Steelhead show directed movement toward the trap entrance; if some fish do not, document the behavior patterns for those specific fish in the tailrace.
3) Determine if Steelhead 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 Steelhead 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 Steelhead that do not enter or which choose to leave the Merwin Dam tailrace and move back downstream.
6) Determine the condition of Steelhead that are captured by the trap, as a function of individual fish energetic state, and rates of descaling, injury, and reflex impairment.
7) Continue to assess how environmental conditions are associated with interannual differences in *ATE*.

Results will be presented for, and comparisons made between, trap Naïve and trap Non-Naïve fish within each of the above objectives, when appropriate. A subset of the trap Naïve fish were also recycled through the system in order to further evaluate potential behavioral effects associated with fish handling and processing. This group is referred to as Non-Naïve$_2$ fish, and comparisons among this group and others are made when appropriate.

METHODS

Fish Collecting and Tagging

All fish included in this study were blank wire tagged (BWT) hatchery Winter Steelhead (hereafter, 'Steelhead') collected and tagged by PacifiCorp staff from late-February through early-May 2018 (for more information on origin of BWT hatchery Winter Steelhead see PacifiCorp 2014). Estimates of core passage metrics and behaviors were made for the following three release groups of tagged Steelhead:

- Trap **Non-Naïve** release group – fish were captured and tagged at the Merwin Dam Adult Fish Collection Facility before being transported and released into the NF Lewis River ~ 0.6 km (0.4 mi) downstream of Merwin Dam at the Merwin Boat Launch (Figure 1). This release group is analogous to fish used to estimate core metrics in previous study years, and thus allows interannual comparisons of core metrics across the study years.
- Trap **Naïve** release group – fish were captured by tangle netting and angling, tagged and released in the NF Lewis River. An assumption is that none of the fish included in this release group previously encountered the trap at Merwin Dam. Trap Naïve fish were included to compare core passage metrics of fish that were previously captured (i.e., trap Non-Naïve fish) with fish that had not been previously captured (i.e., trap Naïve fish).
- Trap **Non-Naïve$_2$** release group – this release group consisted of seven trap Naïve fish that were initially captured as described above for trap Naïve fish, then re-captured at the Merwin Dam Adult Fish Collection Facility, transported, and released downstream at the Merwin Boat Launch (Figure 1). Trap Non-Naïve$_2$ fish were included to enable "dependent" or "within-subject" comparisons of initial rates of return and capture with second-pass rates of return and capture, within a single group of fish. With large enough sample size, analysis of this group could inform inference of whether individuals were less likely to return to Merwin Dam after being previously trapped. For the purposes of comparisons, the Trap Non-Naive$_2$ group was considered a separate release group from the trap Non-Naïve group, as these trap Non-Naive$_2$ fish were handled twice (once during tangle netting and then again at Merwin Dam).

Following capture and prior to release, all fish underwent the same tagging procedure. Briefly, individual fish were transferred into a sampling trough, fork length was measured to the nearest centimeter, a visual assessment of injury was made, a passive integrated transponder (PIT; Full Duplex, 12.5mm, 134.2 kHz) was injected into the dorsal sinus, and a radio transmitter (Lotek MCFT-3a; 166.776 MHz; 16 mm in diameter and 46 mm in length and had a mass of 16 g, giving them a weight of 157 millinewtons in air but only 66 millinewtons in water) was inserted gastrically (Figure 2). Latex tubing was used to reduce tag regurgitation for the gastric implants. Radio transmitters were programmed with a burst rate of 5 s, staggered by 0.5 s intervals within release groups (i.e., each group contained fish implanted with tags bursting at 4.5 s, 5 s, and 5.5 s intervals).

To further explore the mechanisms underlying fish passage behavior after release and to account for potential physiological effects of different capture methods (i.e., tangle netting versus fish trapping at the dam), individual fish condition was quantitatively assessed prior to release using two methods. First, Reflex Actions Mortality Predictors (RAMP; indicators of acute stress from capture and handling procedures) were assessed for each fish following protocols outlined in Raby et al. (2012). Briefly, five reflexes were assessed categorically (0 = unimpaired, 1 = impaired), and an index was then calculated for each fish based on the proportion of reflexes that were impaired. Additionally, to understand how energetic reserves could influence fish behavior after release, muscle lipid content (a primary depot of energy reserves in salmonids) was estimated for each fish, using handheld microwave radio emitters (Distell Fatmeters, https://www.distell.com/), following protocols presented in Caldwell et al. (2013) (Figure 2).

All fish were allowed to recover following the tagging procedure. Fish tagged at the tangle netting site and angling downstream (i.e., Naïve fish) were released immediately overboard following the tagging procedure. Fish tagged at the Merwin Fish Collection Facility (i.e., Non-Naïve and Non-$Naive_2$ fish) were transferred to a water tank on the back of a truck and transported to the release site at the Merwin Boat Launch. A maximum of 10 fish were tagged and released on any given day to reduce the frequency of tag collision.

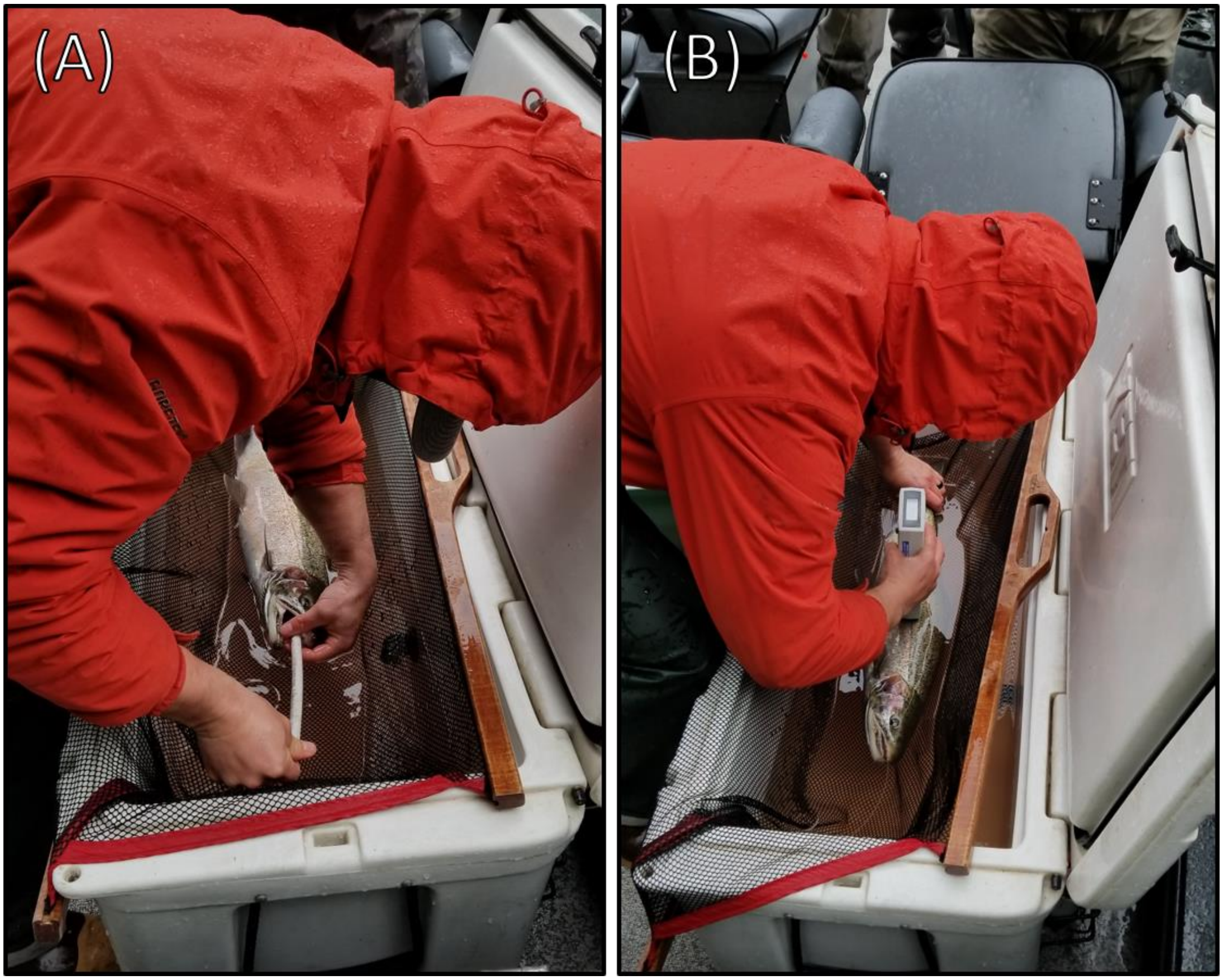

Figure 2. Photos taken during tagging procedure at the tangle netting site. Photos show radio tag being inserted gastrically (A) and Fatmeter being used to measure muscle lipid content (B). Photos courtesy of PacifiCorp.

Fish Tracking

Following release, movements of tagged fish were monitored using fixed radio telemetry stations consisting of 18 detection sites strategically positioned within three distinct study areas (see Table 2, Figure 1, Figure **3**, and Figure **4** for individual site descriptions and locations):

- Downstream of Merwin Dam
    - *n*=7 detection sites extending from the confluence of the Lewis River and Columbia River to the Boat Launch downstream of Merwin Dam; Table 2, Figure 1
- Merwin Dam tailrace
    - *n*=6 detection sites within the tailrace with entrance and exit sites at the Bridge and immediately outside the trap entrance; Table 2; Figure 3; and
- Merwin Dam trap
    - *n*=5 detection sites starting at the entrance to the trap ladder system extending to the trap holding area; Table 2; Figure 4

Each detection site was deployed in combinations with receivers (18 SRX800D). Receivers had the ability to store approximately 1 million detection records each.

Detection site locations in 2018 were identical to those used in 2017 with these exceptions:

- North Shore Short (NSS) and North Shore Long (NSL) receivers were combined in 2018 to create one North Shore (NS) receiver.
- South Shore Short (SSS) and South Shore Long (SSL) receivers were combined in 2018 to create one South Shore (SS) receiver.
- Pool 3 receiver was removed from trap ladder system.
- Lewis River Mouth (LRM) site added – furthest downstream detection site ~ 2.5 km upstream of the confluence of the Lewis River and Columbia River. This antenna site was used to assess whether tagged fish potentially exited the Lewis River.
- East Fork Lewis River (EFL) site added – located in the East Fork Lewis River ~ 3 km upstream of its confluence with the Lewis River. This antenna site was used to assess straying rates of tagged fish into the East Fork Lewis River, a tributary suspected of attracting strays.
- Cedar Creek (CDC) site added – located in Cedar Creek ~ 1 km upstream of its confluence with the NF Lewis River. This antenna site was used to assess straying rates of tagged fish into Cedar Creek, a tributary suspected of attracting strays.

Table 2. Antenna locations, abbreviations, descriptions and purpose for all 18 radio receiver sites used in the study. River kilometers (RKM) are presented as kilometers from the Pacific Ocean.

Study area	Site code	Site name	Antenna description/location	Purpose of site	RKM
Trap	TRP	Collection Pool	Underwater antenna[2] located a few feet from the hopper transfer pipe outflow	Detects fish first entering the collection pool	171.3
"	HOP	Hopper	Two combined underwater dipole antennas located on the east and west sides of the collection hopper	Detects fish inside the fish hopper and the last few feet of the crowder section	171.3
"	PL4	Pool 4	Underwater dipole antenna located at the entrance of Pool 4 downstream from the fish crowder	Detects fish before crowder below the collection hopper	171.3
"	PL2	Pool 2	Underwater dipole antenna located 2 feet from the Pool 2 entrance on the northwest wall of Pool 2	Assesses fish passage and residence time near the Fyke weir	171.3
"	ENT	Entrance	Underwater loop-V antenna at downstream end (entrance) of Trap.	Determines when fish are inside the Trap	171.3
Tailrace	APR	Approach	3 element antenna pointed vertically at Trap entrance	Monitors fish as they approach the Merwin Trap	171.3
"	NS	North Shore	Two radio antennas, one long range 8-element antenna and one short range 3 element antenna, combined into one site	Monitors the North shore of the tailrace	171.3
"	SS	South Shore	Two radio antennas, one long range 8-element antenna and one short range 3-element antenna, combined into one site	Monitors the south shore of the tailrace to the APR site	171.2
"	PWN	Powerhouse North	3 element antenna pointed north parallel to the front of the tailrace deck	Monitors fish in front of the northern half of the Powerhouse	171.3
"	PWS	Powerhouse South	3-element antenna pointed south along the front of the tailrace deck	Monitors fish in front of the southern half of the Powerhouse	171.3
"	BRG	Bridge	Four 3-element antennas located equidistantly along the downstream section of the bridge. The north 2 antennas were amplified producing a uniform detection zone.	Indicates when upstream adult Steelhead first enter the tailrace and are attempting to migrate above Merwin Dam.	171.1
Down-stream	BLU	Boat Launch Upstream	6-element antenna downstream of the BRG site	Determines direction of fish migration relative to the fish release site at the Merwin Dam Boat Launch	170.8

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[2] Underwater loop-V antenna was used until approximately April 1st, after which an underwater dipole antenna was used at this location.

Study area	Site code	Site name	Antenna description/location	Purpose of site	RKM
"	BLD	Boat Launch Downstream	6-element antenna downstream of the release site	Determines direction of fish migration relative to the fish release site at the Merwin Dam Boat Launch	170.3
"	CDC	Cedar Creek	6-element antenna in Cedar Creek	Monitor fish entering Cedar Creek	166.3
"	LRH	Lewis River Hatchery	6-element antenna at the NF Lewis River/Cedar Creek confluence	Determines direction of fish migration relative to the Merwin Dam release site	165.2
"	BBL	Bed Breakfast Lewis River	6-element antenna on the NF Lewis River in Woodland, Washington	Confirms fish in study area	152.0
"	EFL	East Fork Lewis River	6-element antenna on the East Fork Lewis River	Monitor fish entering the East Fork Lewis River	148.7
"	LRM	Lewis River Mouth	6-element antenna on the Lewis River near it’s confluence with the Columbia River	Confirm fish in the study area and potential of fish exiting the Lewis River	142.5

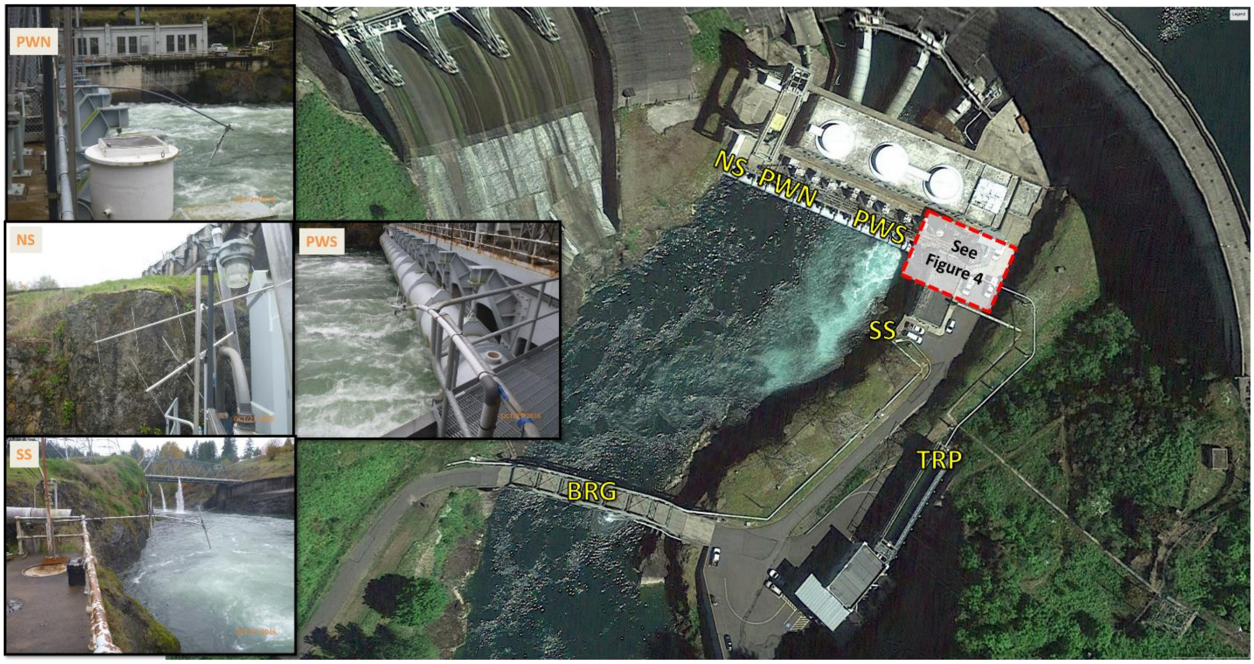

Figure 3. Merwin Dam tailrace area with locations of stationed antennas and pictures of select antenna orientations. All antennas listed in this figure are aerial, except for the Trap. Details of antennas deployed within the trap are shown on the trap schematic in Figure 4. Aerial image taken from Google Earth. All other photos provided by Cramer Fish Sciences.

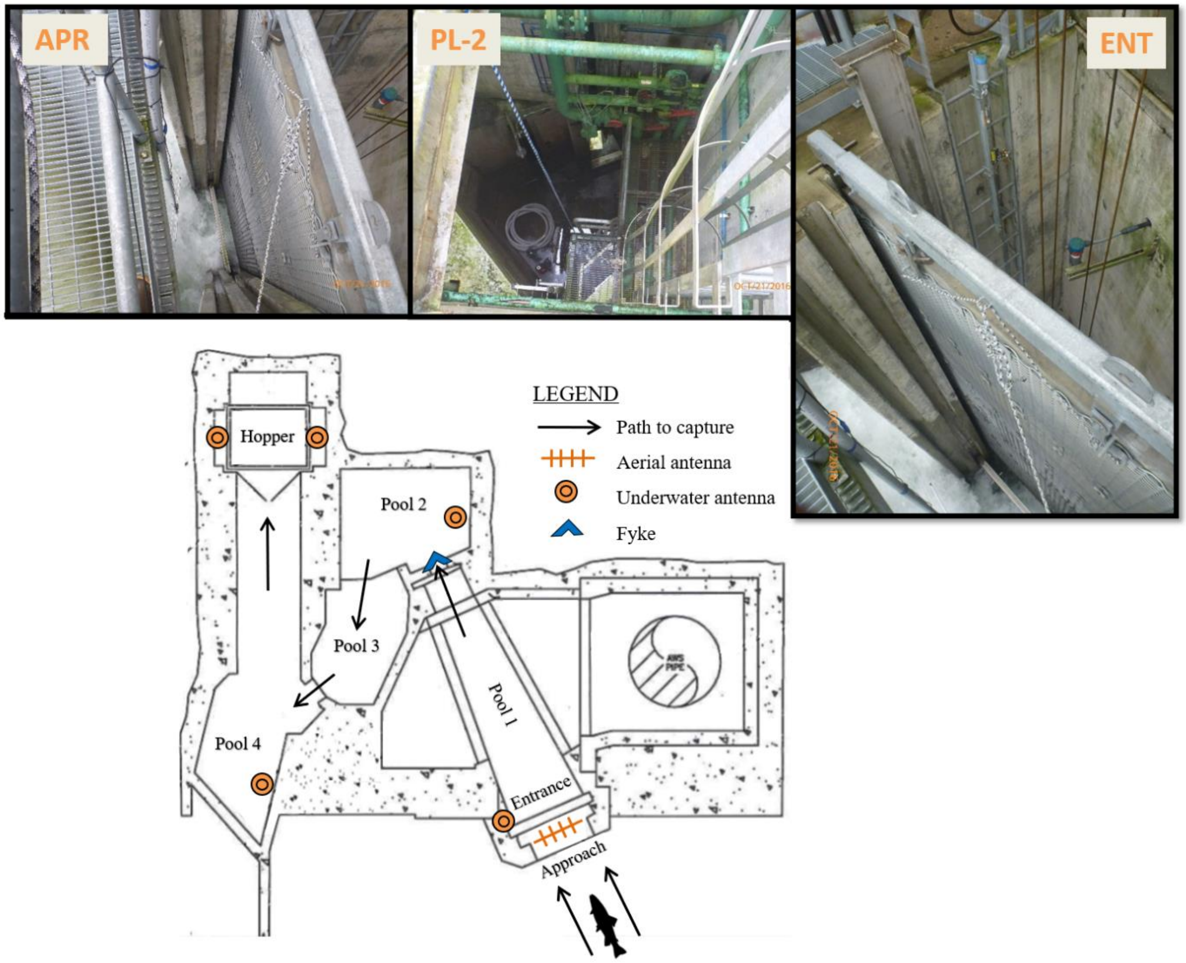

Figure 4. Trap schematic showing the locations of antenna arrays, with arrows showing the progressive movements fish make to reach the hopper and pictures of select antenna orientations. Photos provided by Cramer Fish Sciences.

Detection capabilities

Tag detection ranges for each radio receiver were designed to meet specific goals related to each detection site and study area. For example, radio detection sites downstream of the tailrace were designed to act as ‘gates’ that detect fish passing the site in either direction across the entire river channel. Similarly, the Bridge site acts as the ‘start gate’ for fish entering the tailrace. Detection regions within the tailrace were designed to create overlapping regions that identify specific fish movements within the tailrace (see generalized tailrace detection regions presented in Figure 5). Detection regions within the trap were designed to detect fish within the respective trap location.

Detection ranges were evaluated manually for all receivers in the tailrace (see Appendix A-1 for additional details on range testing protocols). Following initial set-up and range testing, routine inspections of detection data were also made throughout the study to verify detection ranges remained as intended. Beacon tags (i.e., radio tags that are programmed to emit signals once every hour) were deployed at a fixed location near each detection site, except Pool 4, to confirm all antennas continued to function properly over the study duration.

Figure 5. Locations of intended detection regions for six radio receivers located from the bridge upstream and into the fish passage facilities at Merwin Dam.

Data Management and Processing

Receiver sites were inspected and downloaded either weekly or bi-weekly throughout the study. Raw detection data were filtered to remove noise and tag codes not included in the study, and filtered data were compiled into a Microsoft Access database (for additional details see Appendix A-2). A second filtering process developed by Stevens et al. (2015) was applied the data. This filtering process is described in previous reports (e.g., see Drenner et al. 2018b) and presented in Appendix A-2, in addition to results pertaining data management and processing.

Following data filtration, all individual fish detection histories were visually inspected.

Analytical Approach

Objective 1: Determine trap effectiveness based on ATE and other core metrics (a), compare estimates to the ATE performance standard of 98% (b), test for temporal trend in ATE (c), and compare ATE estimates between Naïve and Non-Naïve release groups (d)

Objective 1a: Estimate core passage metrics

Adult trap efficiency (ATE) for Merwin Dam is the percentage of actively migrating adults that are caught in the Merwin fish trap. 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}, one of two metrics that have been developed in order to evaluate trap efficacy (the other being P_{EE}; see below). 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.

As a point of note, ATE_{test} calculated as described above represents a “raw” summary statistic, which does not account for sample size or mathematical properties of binomially distributed proportional data. Estimates of population level proportions based on samples, such as ATE_{test}, tend to miss the true population proportion (ATE) by one standard deviation of the true proportion, which can be thought of as the expected error amount (Dytham 2011). For samples of proportion data, this expected error is equivalent to the standard error (SE) of the estimate. As sample size increases, SE shrinks in proportion to the square root of sample size increase (Dallal 2012). Our method for accounting for sample size and presenting uncertainty of this and other estimates is described below.

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; i.e., fish detected at the trap entrance or any receivers upstream of the trap entrance are considered to have successfully passed the trap entrance), calculated as follows:

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

where:

T is the number of fish that enter the trap, regardless of whether they were eventually captured or returned back to the tailrace (i.e., exited the tailrace) as 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 T_i values equate to lower trap effectiveness:

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

All core metrics (ATE_{test}, P_{EE} and T_i) were estimated separately for each of the three release groups (Naïve, Non-Naïve and Non-Niave$_2$) as well as for a ‘Total’ group of fish consisting of Naïve and Non-Naïve fish combined. Observations (raw estimates) are presented in tables for the purposes of reporting and data summary. In addition, to generate informed estimates of metrics, and to facilitate statistical comparisons between core metrics and targets, and comparisons of core metrics among groups, Bayesian methods were used to infer posterior probability distributions (posteriors) of core metric values for each group, using the Bolstad package (Curran & Bolstad 2018) within Program R (R Core Team 2018). Proportional data tend to exhibit binomial distributions, which are best modeled using beta prior probability distributions (priors). Given numerous operational, infrastructural, and environmental differences among previous study years, we elected to use uniform Bayes-Laplace (beta (1, 1)) priors, to minimize biasing current year’s results with results from non-comparable years. As a note, numerous additional priors were evaluated, including Jeffreys (beta (0.5, 0.5)), Haldane (beta (0.01, 0.01)), and a series of vague priors incorporating previous years’ data, and results were generally qualitatively similar.

The result of these efforts is a series of posteriors for each core metric for each group. Importantly, posteriors contain all of the information (i.e., prior assumptions and data), and provide the complete inference from the Bayesian perspective, including statistical moments concerning central tendency and precision (Bolstad 2007). Thus, the posteriors are the source of Bayesian Credible Intervals (BCIs, aka Highest Density Intervals or HDIs), and form the basis of comparisons between metrics and targets, and among groups. HDIs are the Bayesian analog to frequentist Confidence Intervals (CIs), with the benefit that HDIs express precision as the probability of a value given the data, rather than vice versa, as is the case for frequentist CIs.

Objective 1b: Evaluate core passage metrics against performance standards

Core passage metrics were compared to performance standards by inferring precision of posterior estimates based on 95% HDIs. 95% HDIs were estimated for ATE_{test} values associated with each release group using the Bayesian posteriors derived as explained above. These 95% HDIs encompass the range of parameter values that are 95% most credible, given the priors and the data. After generating a 95% HDI, testing a hypothesis regarding threshold targets (i.e., comparing ATE_{test} to ATE_{target}) at 5% alpha rate simply amounts to comparing the target value to the HDI range, and determining if the target falls within the HDI. Additional insights were generated by determining the actual posterior probability density for ATE_{target} for each group.

Objective 1c: Test for temporal trends in ATE

To determine if *ATE* changes over time, generalized linear models (GLM) were used to model individual fish passage success based on release date. The GLMs used logistical regression with a binomial response variable, passage success, being either zero (not re-captured) or one (re-captured). Temporal trends were examined separately for Naïve and Non-Naïve fish, and separately for fish that entered the tailrace and for all fish released.

Objective 1d: Compare ATE between trap Naïve and Non-Naïve fish

With posteriors for each metric and group, comparisons of metrics among groups amounts to comparing posteriors (i.e., summary moments, HDIs, and entire distributions), to derive the estimated difference in means and the overall probability of difference between groups. To facilitate this process, a Bayesian proportions test was used to compare ATE_{test} between Naïve and Non-Naïve fish, using the Bolstad (Curran & Bolstad 2018) and BayesianFirstAid (Bååth 2014) packages within Program R (R Core Team 2018). All analyses were conducted with uniform Bayes-Laplace priors.

Objective 2: Determine if Steelhead 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, 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 distinct zones: downstream, tailrace, and trap. The Bridge receiver separated downstream nodes from tailrace nodes, and the Entrance receiver separated tailrace nodes from trap nodes. Using these logical labels, the transition matrix created from the raw transition data were adjusted in the following ways:

- Downstream transitions were linearized.
    - e.g., (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.
    - e.g., (Boat Ramp→ Powerhouse South) became (Boat Ramp→Holding Pool; Holding Pool→Bridge; Bridge→ Powerhouse South), and likewise for the reverse.
- Transitions from the tailrace to the trap were forced to go through receiver Entrance.
    - e.g., (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. 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;
- the difference between individual and instantaneous transition rates, which we define here as the milling index, MI

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

- 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.

To evaluate behavioral differences between Naïve and Non-Naïve fish, comparisons were made based on the following:

- visualization of movements of Naïve and Non-Naïve fish using network diagrams

- Wilcoxon rank sum test comparing median number of sites visited between Naïve and Non-Naïve fish

- Transition rates and milling index of Naïve and Non-Naïve fish

Objective 3: Determine if Steelhead 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 both visually and statistically analyze:

1) Median residence times per site; and

2) Total time spent by Steelhead 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 effectively blanket 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 duration that Steelhead are present in Merwin Dam tailrace, and compare this 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 to account for fish milling behavior, and to remain comparable with previous reports (Stevens et al. 2015; Caldwell et al. 2016; Drenner et al. 2017). Estimates for tailrace passage time are presented for:

- all fish that entered the tailrace;
- fish that entered the tailrace but not the trap;
- fish that entered the trap but were not re-captured; and
- fish that were re-captured.

In addition, tailrace passage times are presented separately for Naïve and Non-Naïve fish. A non-parametric Wilcoxon rank sum test was used to test if median tailrace passage times for Naïve and Non-Naïve fish were statistically different.

Objective 5: Describe the movement and behavior of tagged Steelhead 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 detection site), 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 Steelhead that are captured by the trap, as a function of individual fish energetic state, and rates of descaling, injury, and reflex impairment.

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. In addition to qualitative assessments, two additional methods were used to assess fish condition, measurement of fish energetic state and reflex impairments.

Individual fish energetic state was assessed by measuring muscle lipid content of fish prior to being released. Relationships with fish energetic state was evaluated for: a) release date (linear regression); b) release group (i.e., Naïve versus Non-Naïve fish; generalized linear models); and c) fate after release (i.e., trapped versus not trapped; Wilcoxon rank sum tests)

Reflex impairment was assessed for individual fish following RAMP protocols (see Raby et al. 2012); the resulting RAMP scores being a proportion of the five assessed reflexes that were impaired (e.g., the closer the value to one, the more reflexes were impaired). Descriptive statistics for RAMP scores are presented, however, no formal statistical tests were applied due to the small amount of RAMP score variability observed among individual fish.

Objective 7: Continue to assess environmental conditions as they relate to interannual differences in ATE.

Previous data exploration of environmental and operational conditions in the NF Lewis River and at Merwin Dam indicated total discharge from the NF Lewis River could be related to observed interannual difference in ATE_{test}, the trend suggesting that higher NF Lewis River discharge was potentially associated with lower ATE_{test}.

NF Lewis River discharge (cfs) data were obtained from USGS (USGS 2018. Data observations for total NF Lewis River discharge are presented along with discharge data from previous study years to provide context.

RESULTS

Summary

From 22 February – 02 May 2018, 92 adult BWT Winter Steelhead (38 females; 54 males, FL = 60 – 92 cm) were collected, implanted with radio tags, and released into the NF Lewis River below Merwin Dam to continue their upstream migrations to the Merwin Dam fish trap. Of those 92 tagged Steelhead, 73 were trap Non-Naïve fish and 19 were trap Naïve. Of the 19 trap Naïve fish, seven were released downstream after being captured in the Merwin Dam fish trap; these seven fish constituted the trap Non-Naive$_2$ release group. Because these seven fish were accounted for twice, being included in both the trap Naïve and trap Non-Naive$_2$ groups, 99 individual detection histories are represented among the three release groups, but only 92 individual fish were used in the study. To avoid double counting individual fish, below we present results for the 92 fish constituting the Naïve and Non-Naïve release groups, which are visualized in Figure 6 and summarized along with instances of tag shed, tag failure and mortalities. Results for the seven Non-Naïve$_2$ fish are presented separately. Summary data on individual fish and their detections are presented in Appendix A-3.

- Three fish shed their radio tag but were later re-captured in the Merwin Dam fish trap and identified by PIT tag. One fish was reported recaptured by a fisherman at the Lewis River Golf Course (the tag was removed, and fish released)
    - *Tag sheds and fisheries recaptures are accounted for in the core metrics presented herein (e.g., fish re-captured without detections in the trailrace or trap were added to total counts of fish that entered the tailrace and were trapped).*
- 92 fish (100% of total) were detected at least once somewhere within the detection array.
    - *All seven (100% of total) Non-Naïve$_2$ fish were also detected within the detection array.*
- None (0%) of the tagged fish were detected in either the East Fork Lewis River or Cedar Creek.
- Among radio telemetry sites with fish detections, the Lewis River Mouth (n = 4) and the Bed & Breakfast (n = 6) sites detected the fewest fish; the Boat Launch Downstream (n = 85) site detected the most fish.
    - *Three Non-Naïve$_2$ fish were detected at the Lewis River Mouth and the Bed & Breakfast site.*

- 83 fish (90% of total) entered the Merwin Dam tailrace. One of these was only detected at the Bridge site, and never further into the tailrace. This fish was later recaptured in the trap and identified as a tag shed.
    - *Five Non-Naïve$_2$ fish (71% of total) entered the Merwin Dam tailrace.*
- 81 fish (88% of total) were detected in the Approach zone immediately outside the trap entrance.
    - *Four Non-Naïve$_2$ fish (57% of total) were detected in the Approach zone.*
- 82 fish (89% of total) entered the trap entrance (i.e., were detected at the Entrance site or further upstream), 100% of which were detected past the fyke at the base of Pool 2. Low numbers of fish detected at the Entrance site compared to upstream sites indicated fish passed the Entrance site without being detected. The trap entrance has high flows and no holding areas for fish, so fish presumably move quickly through this area, thereby avoiding detection on the Entrance receiver.
    - *Four Non-Naïve$_2$ fish (57% of total) entered the trap entrance.*
- 77 fish (84% of total), comprising 33 females (87% of 38 tagged) and 44 males (81% of 54 tagged), were re-captured at the Merwin Dam Adult Fish Collection Facility.
    - *Four Non-Naïve$_2$ fish (57% of total) were re-captured*

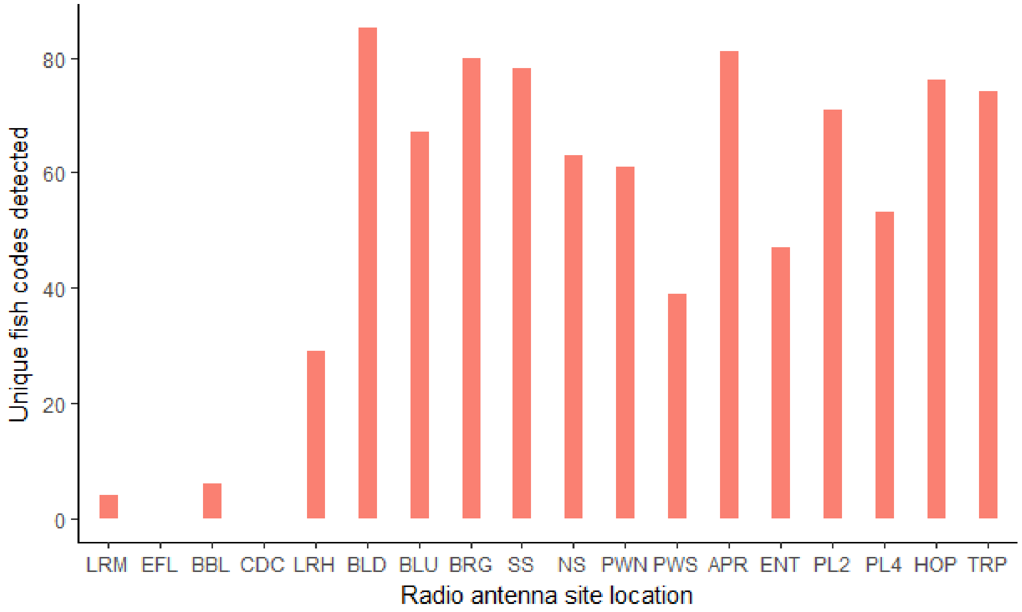

Figure 6. Numbers of unique fish codes (i.e., fish IDs) detected on each radio receiver site within the study area. See Figure 1, Figure 3, and Figure 4 for receiver locations. Note that a total of 92 unique fish codes are represented in this figure (i.e., it excludes the Non-Naive$_2$ release group of fish).

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%

Objective 1a: Estimate core passage metrics

During the 2018 study season, a total of 92 tagged Steelhead were represented between the Naïve and Non-Naïve release groups (*N*), of which 83 were detected within the Merwin Dam tailrace (*M*), 82 were detected entering the Merwin Dam trap (*T*), and 77 were ultimately captured (*C*). These counts provide the basis for raw estimation of the core metrics: P_{EE} = 99% (82/83), ATE_{test} = 93% (77/83) and T_i = 6% (5/82; see Table 3).

All of trap Naïve fish that entered the tailrace entered the trap (raw P_{EE} = 100%), and all but one of the trap Non-Naïve fish that entered the tailrace entered the trap (raw P_{EE} = 99%). Despite high percentages of both trap Naïve and Non-Naïve fish entering the trap from the tailrace, ATE_{test} for the Naïve release group was nine percentage points higher than ATE_{test} for the Non-Naive release group. This discrepancy is reflected by the trap ineffectiveness metric for the trap: for Non-Naïve fish, raw T_i = 8%, indicating that 8% (n = 5) of trap Non-Naïve fish that entered the trap in 2018 were not ultimately captured. In contrast, 100% of trap Naïve fish that entered the trap in 2018 were captured.

Out of the seven Non- Naive$_2$ fish tagged in 2018, five fish entered the tailrace, four fish entered the trap, and four fish were recaptured. Thus, for Non- Naive$_2$ fish in 2018, raw P_{EE} = 80%, raw ATE_{test} = 80% and raw T_i = 0% (Table 3). Statistical comparisons among pairs of release groups that include Non-Naïve$_2$ are limited in scope and power due to: (1) low sample sizes in the Non-Naïve$_2$ release group (*n*=7); and (2) lack of independence among groups, since these fish were originally Naïve fish that were released following capture in the trap. (i.e., they represent repeated measures on individual fish). Therefore, Non-Naïve$_2$ fish are excluded from all quantitative results hereafter, although qualitative comparisons are made in some instances.

Table 3. Summary of passage metrics for tagged Steelhead approaching the tailrace of Merwin Dam during Spring/Summer 2018.

Metric	**Naïve**	**Non-Naïve**	**Non-Naïve$_2$**	**Total (excluding Non-Naïve$_2$ fish)**
Tagged Fish (*N*)	19	73	7	92
Entered the Merwin tailrace (*M*)	16	67	5	83
Entered the Trap (*T*)	16	66	4	82
Captured (*C*)	16	61	4	77
Raw Trap Entrance Efficiency ($P_{EE} = \frac{T}{M}$)	100%	99%	80%	99%
Raw Collection Efficiency ($ATE_{test} = \frac{C}{M}$)	100%	91%	80%	93%
Raw Trap Ineffectiveness ($T_i = \frac{T-C}{T}$)	0%	8%	0%	6%

Objective 1b: Evaluate core passage metrics against performance standards

Core passage metrics (i.e., ATE_{test}) were evaluated against performance standards (i.e., ATE_{target}) for three groups including Naïve and Non-Naïve release groups, as well as a 'Total' group that included both Naïve and Non-Naïve fish.

Total:

The Bayesian posterior ATE_{test} estimate for the Total number of fish that reached the tailrace (n = 83) was 91% (95% HDI = 85-97%). There was a 99.8% posterior probability that the true *ATE* value of the parent population for this group was < 98%. That is, there was less than a 0.2% posterior probability that the true *ATE* of the parent population met or exceeded the target.

Non-Naïve:

The Bayesian posterior ATE_{test} estimate for the Non-Naïve fish that reached the tailrace (n = 67) was 90% (95% HDI = 82-96%. There was a 99.9% posterior probability that the true *ATE* value of the parent population for this group was < 98%. That is, there was less than a 0.1% posterior probability that the true *ATE* of the parent population met or exceeded the target.

Naïve:

The Bayesian posterior ATE_{test} estimate for the Naïve fish that reached the tailrace (n = 16) was 96% (95% HDI = 84 – 100%). There was a 71% posterior probability that the true *ATE* value of the parent population for this group was < 98%. That is, there was a 29% posterior probability that the true *ATE* of the parent population met or exceeded the target.

Objective 1c: Test for temporal trends in ATE

Among release groups, raw ATE_{test} values ranged from 50 – 100% (Table 4), and there was no apparent trend in raw ATE_{test} over time (**Figure 7**).

Table 4. Passage metrics summarized by release date for 2018. See Table 3 for explanation of notation. Note: Naïve and Non-Naïve release groups were combined for this table.

Release Date	*N*	*M*	*T*	*C*	Group raw ATE_{test} (%)
2/22/2018	8	6	6	6	100%
3/2/2018	1	1	1	1	100%
3/12/2018	1	1	1	1	100%
3/13/2018	6	6	5	4	67%
3/19/2018	4	4	4	4	100%
3/20/2018	7	4	4	4	100%
3/23/2018	1	1	1	1	100%
3/29/2018	10	10	10	10	100%
4/2/2018	1	1	1	1	100%
4/15/2018	1	1	1	1	100%
4/19/2018	6	4	4	4	100%
4/25/2018	1	1	1	1	100%
5/2/2018	1	1	1	1	100%
2/28/2018	5	5	5	5	100%
3/7/2018	4	4	4	4	100%
3/8/2018	1	1	1	1	100%
3/28/2018	2	2	2	1	50%
4/3/2018	10	10	10	9	90%
4/4/2018	6	6	6	6	100%
4/11/2018	10	8	8	7	88%
4/17/2018	3	3	3	3	100%
4/24/2018	3	3	3	2	67%
Total:	**92**	**83**	**82**	**77**	**See Table 3**

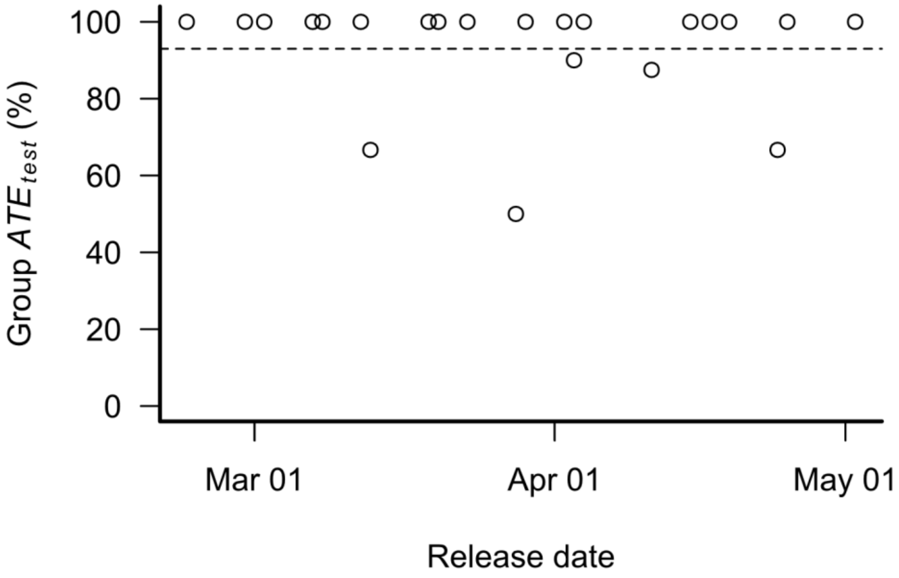

Figure 7. Estimated group raw ATE_{test} by date of release. Dashed line indicates seasonal total raw ATE_{test} estimate for Winter Steelhead in 2018. Open circles are ATE_{test} estimates of all fish released on a given day.

Results from binomial GLMs indicated there was no significant effect of release date on raw re-capture probability for either Non-Naïve (*df* = 72, *p* = 0.68) or Naïve (*df* = 18, *p* = 0.89) fish, and therefore, both release groups were combined in a final model. The final model did not detect a significant effect of release date on raw re-capture probability using either only fish that entered the tailrace (*df* = 82, *p* = 0.62) or using all released fish (*df* = 91, *p* = 0.77; Figure 8).

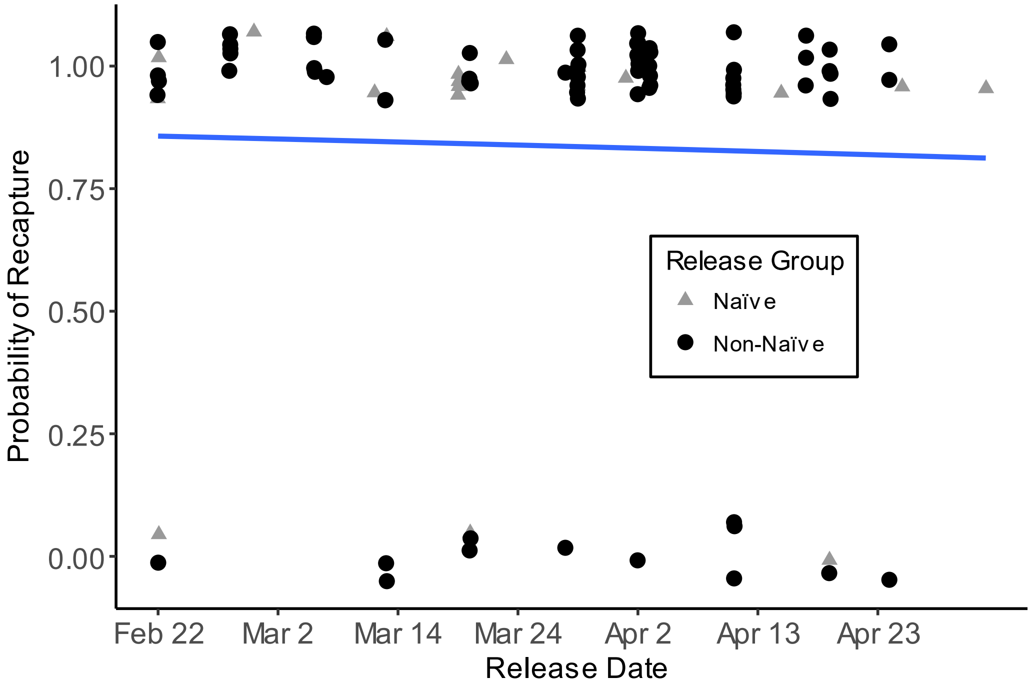

Figure 8. The raw probability of re-capture for individual fish, plotted as a function of release date. Solid circles and triangles represent individual fish from the Non-Naïve and Naïve release groups, respectively. Blue line indicates the predicted probability of re-capture across release date based on logistic regression. Release groups were combined to create logistic regression curve because significant relationships between release date and probability of recapture were not detected for either release group. In addition, all released fish were included in this figure not just those fish that reached the tailrace.

Objective 1d: Compare ATE between trap Naïve and Non-Naïve fish

Initial binomial tests indicated significant differences in ATE_{test} between Naïve and Non-Naïve fish, but this was before accounting for tag sheds.

After adjusting for tag sheds, Bayesian proportions tests indicated an 80% posterior probability that ATE_{test} was truly greater for Naïve fish than for Non-Naïve fish, with an estimated difference of approximately 5% between groups.

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

To facilitate comparisons with previous reports and ease of interpretation, we present Objective 2 results in two sections. First, results for Non-Naïve fish are presented, which are comparable to results from previous studies (i.e., all previous studies used Non-Naïve fish). Next, we present results comparing Naïve and Non-Naïve fish.

Non-Naïve fish

A visual analysis of the network diagram for Non-Naïve Steelhead movements throughout the study area illustrates the tendency of fish to move widely within the tailrace (Figure 9). Key findings include:

1) Fish entering the tailrace upstream of the Bridge receiver most commonly headed south to the South Shore, rather than moving along the North Shore (grey lines leaving Bridge and pointing towards SS are darker than those pointing towards NS in Figure 9).
2) The most frequent pathway that resulted in a detection at just outside of the entrance to the trap was from the South Shore (grey lines pointing towards Approach are darkest from SS in Figure 9).
3) Individuals exhibit milling behaviors (blue lines in Figure 9) near the entrance to the trap, between receivers Approach ↔ Entrance.
4) Within the trap, the majority of milling occurred between Entrance ↔ Pool 2.
5) Milling also occurs immediately downstream of the tailrace between receivers Upper Boat Launch ↔ Bridge.

Figure 9. 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 (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). 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.

Next, we generated a heat map in matrix form, depicting color-coded probabilities of fish moving from one site to another (Figure 10). 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 at the Entrance receiver. Other results shown in the heat map figure include the following:

1) After release, fish were most likely to be next detected at the Boat Launch Downstream (with a probability of 69%) and the Lewis River Hatchery (with a probability of 17%) sites.
2) Once a fish has progressed up to the Bridge site, it has a 44% probability of next being detected at the South Shore site. After the Bridge, there was only a 15% and 14% probability of being detected next on the North Shore and Boat Launch Upstream sites, respectively, each approximately one third the probability of being detected at the South Shore site.
3) There was a high probability of fish being next detected at the nearest upstream site when fish were at the Lewis River Hatchery (with a probability of 85%), Boat Lunch Downstream (with a probability of 86%) and Boat Launch Upstream (with a probability of 78%) sites.
4) Once a fish was detected at the Bed & Breakfast site, there was an 80% probability of either next being detected at the Lewis River Mouth site (with a probability of 40%) or not being detected again within the study area (with a probability of 40%).
5) Once a fish has nosed into the trap at the Entrance receiver, there are eight potential sites at which a fish will be detected next, the most likely of which (with a 76% probability) was outside the trap at the Approach site.
6) Once inside the trap and detected in Pool 2, there was a 60% probability of the fish being detected further into the trap, and a 39% probability of fish being detected downstream at the Entrance site.

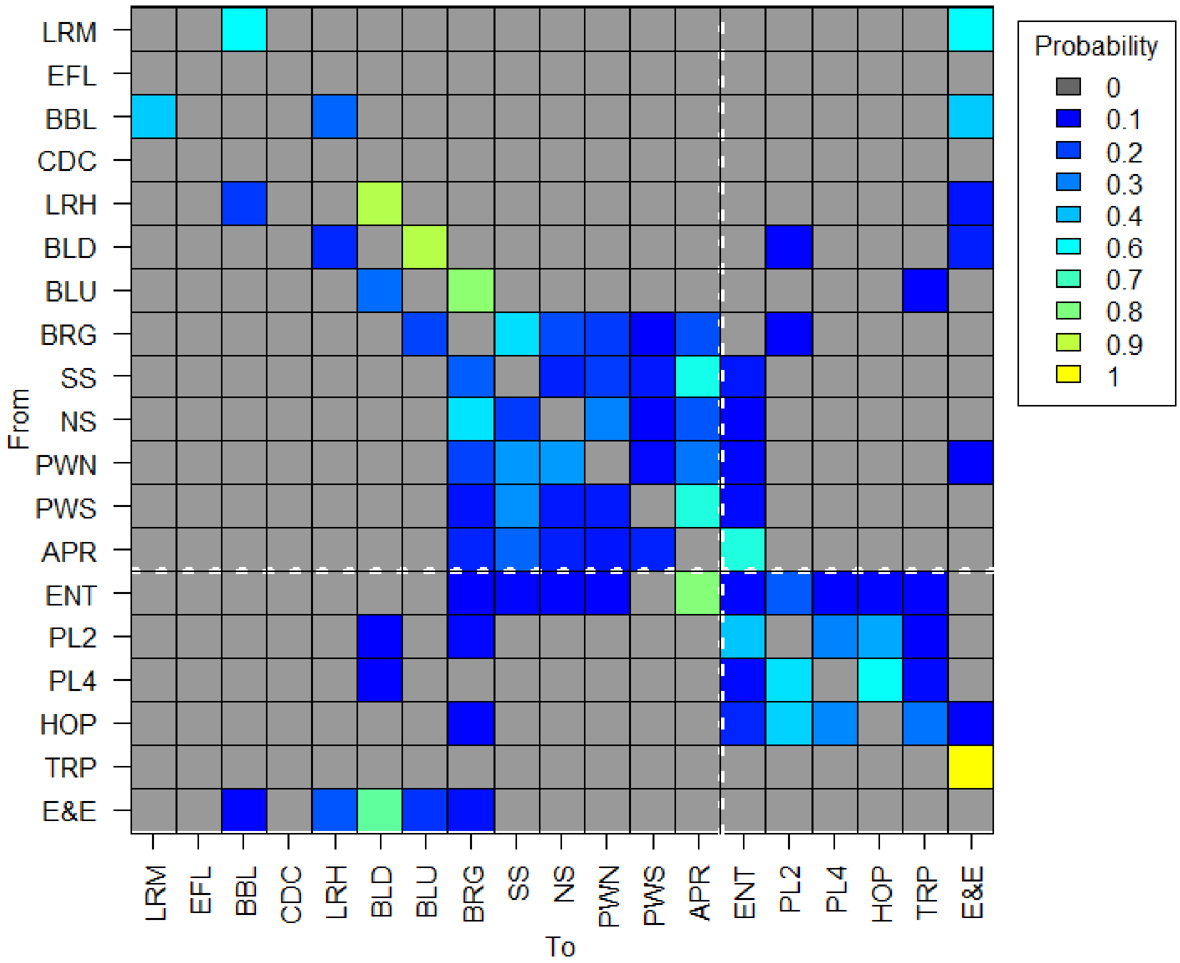

Figure 10. Heat map of the transition probabilities of fish moving from an origin site to all potential destination sites. Each row sums to a probability of 1. Dashed reference lines are added between the Approach and Entrance receivers to show the distinction of a fish being located within or outside of 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 unique site visits by each fish (Figure 11), it is apparent that fish do not tend to move directly into the trap, and there were differences between fish that were eventually trapped compared to fish that were never trapped. The median number of sites visited for fish that were eventually trapped was 45, compared to median value of only 15 or more unique site visits for fish that were not trapped. The mean number of sites visited was higher for fish that were not trapped compared to trapped fish, however, the mean value for not trapped fish was heavily influenced by a single outlier that visited approximately 700 sites.

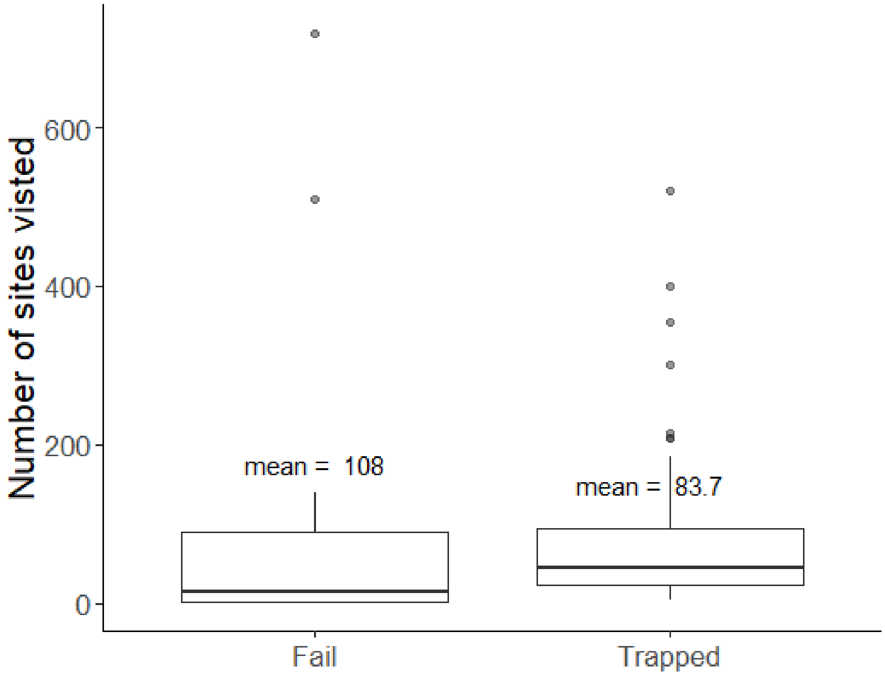

Figure 11. Number of sites visited before being captured (Trapped) or in the case of fish that were not captured, before the end of the study (Fail).

In general, fish tended to move upstream through the telemetry array study area from the Lewis River Hatchery to the tailrace, with most sites having a forward transition probability greater than 50% ($p \geq 0.50$) (Table 5). Additional results based on transition probabilities presented in Table 5 included:

- In the tailrace, fish tended to mill along the North Shore, but not along the South Shore.
- Fish had the greatest probability of transitioning to the next upstream receiver when fish were detected at the Boat Launch Downstream and the Bridge sites.
- Entrance, Hopper and Pool 2 exhibited the greatest degree of milling, as evidenced by the greatest *MI* values for both collected and non-collected fish.

Transition probabilities and milling behavior were not substantially different between collected and not collected fish (Table 5). However, compared to fish that were collected, fish that were not collected had lower probabilities of transitioning forward from all sites downstream of the tailrace.

Table 5. 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}. Positive values of *MI* suggest that fish tend not to move forward from that location. Site specific P_{single} or P_{all} <0.5 are shaded blue, and *MI* >0.000 are shaded green. P_{single} *and* P_{all} values are provided for fish not collected (i.e., *Fail*), for fish collected (i.e., *Pass*), and for collected and not collected fish combined (i.e., *Total*). For site abbreviations, see Table 2.

Receiver	**$P_{single, Fail}$ (not collected)**	**$P_{all, Fail}$ (not collected)**	**MI_{Fail}**	**$P_{single, Pass}$ (collected)**	**$P_{all, Pass}$ (collected)**	**MI_{Pass}**	**P_{single} (collected and not collected)**	**P_{all} (collected and not collected)**	**MI_{Total}**
LRM	0.500	0.500	0.000	NA	NA	NA	0.500	0.500	0.000
BBL	0.000	0.000	0.000	1.000	1.000	0.000	0.200	0.200	0.000
LRH	0.200	0.200	0.000	1.000	1.000	0.000	0.852	0.852	0.000
BLD	0.450	0.686	-0.236	0.896	0.922	-0.026	0.804	0.862	-0.058
BLU	0.563	0.565	-0.003	0.771	0.837	-0.066	0.741	0.784	-0.043
BRG	0.767	0.846	-0.079	0.838	0.870	-0.032	0.829	0.866	-0.037
SS	0.407	0.587	-0.180	0.525	0.639	-0.114	0.511	0.632	-0.121
NS	0.476	0.523	-0.047	0.508	0.413	0.094	0.503	0.434	0.070
PWN	0.263	0.227	0.036	0.275	0.249	0.026	0.273	0.244	0.029
PWS	0.300	0.533	-0.233	0.485	0.592	-0.107	0.461	0.583	-0.122
APR	0.207	0.732	-0.525	0.271	0.501	-0.229	0.264	0.562	-0.298
ENT	0.350	0.068	0.282	0.518	0.255	0.263	0.500	0.199	0.301
PL2	0.500	0.567	-0.067	0.733	0.598	0.136	0.706	0.594	0.112
PL4	0.429	0.409	0.019	0.618	0.546	0.072	0.602	0.531	0.071
HOP	0.000	0.000	0.000	0.471	0.259	0.211	0.435	0.229	0.206

When evaluating transition probabilities at each site to determine how fish moved through the system, it becomes apparent that non-recaptured fish tended to move further downstream from the tailrace sites (Figure 12). However, within the tailrace, spatial behavior patterns were similar between successfully and unsuccessfully re-captured fish.

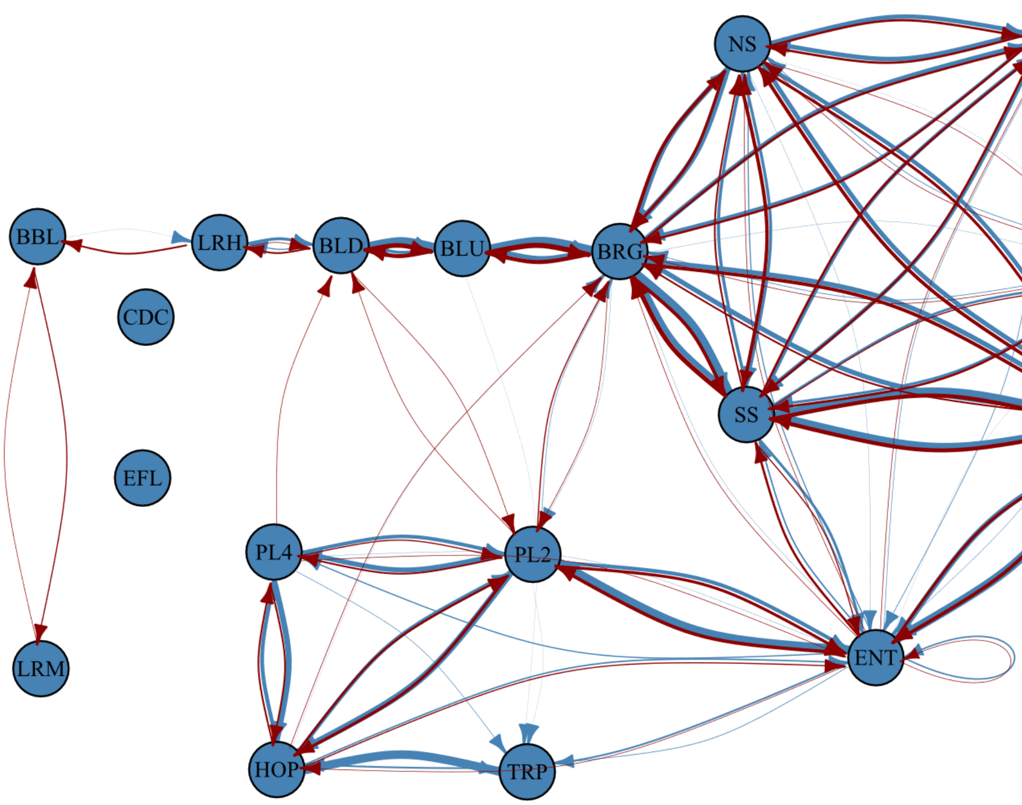

Figure 12. Network diagram of fish movement within the study area at Merwin Dam grouped by fish that ultimately are re-captured (blue) or failed to be re-captured (red) from 2018. Path thickness and color are scaled based on the total number of transitions which occurred between sites with fish as the sample unit. This graphic depicts the movements of 92 fish; 77 that were successfully re-captured (i.e., last detected at Trap) and 15 that were unsuccessful. This figure does not include movements of fish that experienced tag shed or tag failure.

Comparisons between Non-Naïve and Naïve fish

Comparisons of transition probabilities at each site between Naïve and Non-Naïve fish indicated Naïve fish had fewer downstream movements from the Bridge and after entering the trap compared to Non-Naïve fish (Figure 13). However, within the tailrace, spatial behavior patterns were similar between Naïve and Non-Naïve fish.

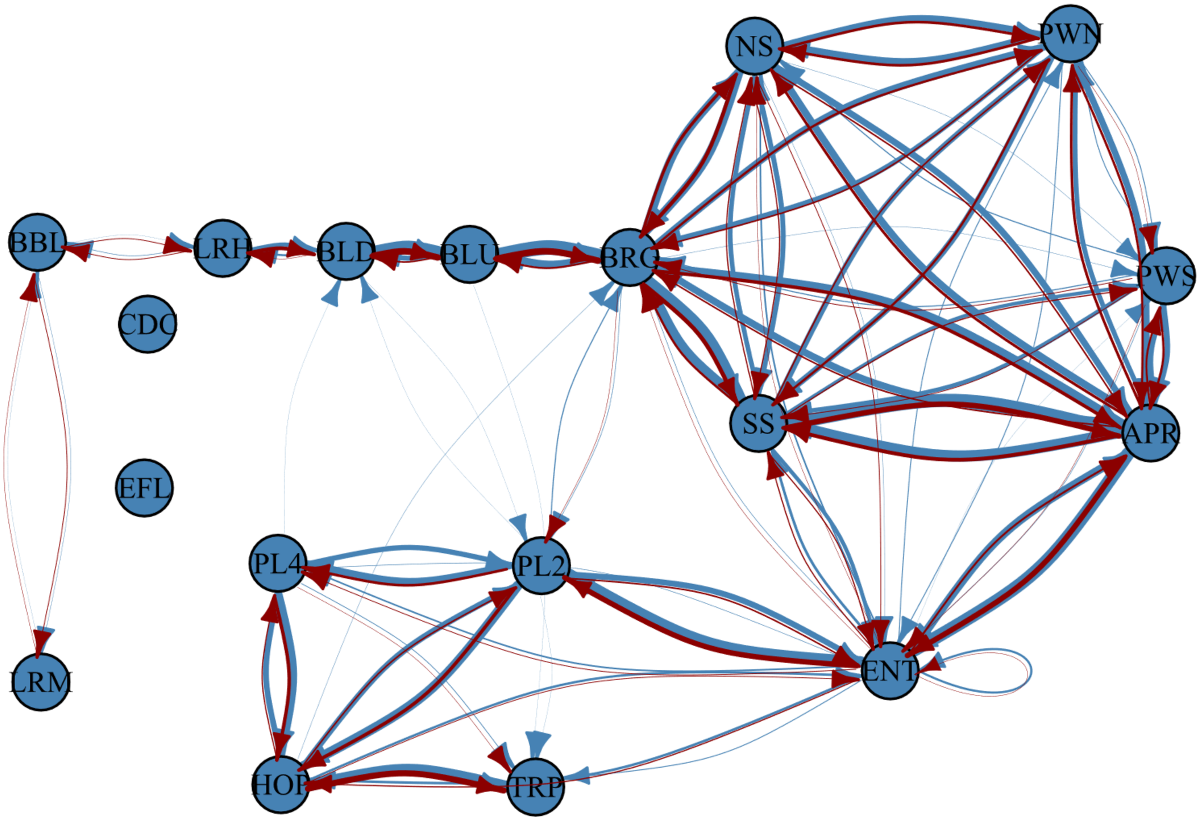

Figure 13. Network diagram of fish movement within the study area at Merwin Dam grouped by Naïve (red) or Non-Naïve (blue) release groups from 2018. Path thickness and color are scaled based on the total number of transitions which occurred between sites with fish as the sample unit. This graphic depicts the movements of 92 fish including 19 Naïve fish and 73 Non-Naïve fish. This figure does not include movements of fish that experienced tag shed or tag failure.

Results from a Wilcoxon rank sum test comparing the median number of unique site visits between Naïve and Non-Naïve fish indicated Naive fish visited significantly fewer sites prior to being captured compared to Non-Naïve fish (W = 641.5, p = 0.020). On average, Naïve fish visited 31 fewer sites compared to Non-Naïve fish (Figure 14).

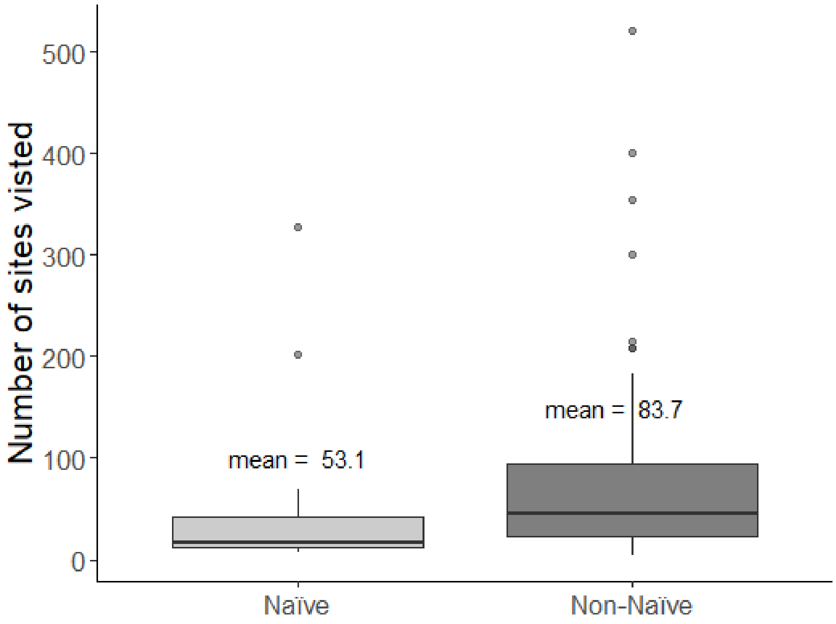

Figure 14. Number of sites visited before being trapped for Naïve and Non-Naïve fish.

Compared to Non-Naïve fish, Naïve fish generally had higher probabilities of moving forward from sites within the tailrace and trap, as well as at the Boat Launch sites directly downstream of the tailrace (Table 6). The locations where fish tended to mill were the same between Naïve and Non-Naïve fish (Table 6).

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}. Positive values of *MI* suggest that fish tend not to move forward from that location. Site specific P_{single} or P_{all} <0.5 are shaded blue, and *MI* >0.000 are shaded green. P_{single} *and* P_{all} values are provided for Naïve and Non-Naïve fish. For site abbreviations, see Table 2.

Receiver	**P_{single} (Non-Naïve)**	**P_{all} (Non-Naïve)**	**$MI_{Non-Naïve}$**	**P_{single} (Naïve)**	**P_{all} (Naïve)**	**$MI_{Naïve}$**
LRM	0.500	0.500	0.000	0.333	0.333	0.000
BBL	0.200	0.200	0.000	0.500	0.400	0.100
LRH	0.852	0.852	0.000	0.833	0.769	0.064
BLD	0.804	0.862	-0.058	0.895	0.917	-0.022
BLU	0.741	0.784	-0.043	0.810	0.853	-0.043
BRG	0.829	0.866	-0.037	0.875	0.886	-0.011
SS	0.511	0.632	-0.121	0.606	0.689	-0.083
NS	0.503	0.434	0.070	0.500	0.367	0.133
PWN	0.273	0.244	0.029	0.250	0.250	0.000
PWS	0.461	0.583	-0.122	0.636	0.688	-0.051
APR	0.264	0.562	-0.298	0.298	0.586	-0.288
ENT	0.500	0.199	0.301	0.633	0.223	0.411
PL2	0.706	0.594	0.112	0.800	0.563	0.238
PL4	0.602	0.531	0.071	1.000	1.000	0.000
HOP	0.435	0.229	0.206	0.640	0.471	0.169

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

Tailrace & trap behavior

Once in the tailrace, Steelhead tended to use the south side of the tailrace more than the north side based on higher numbers of visits and higher median residence times at sites on the south side compared to sites on the north side (Figure 15; Figure 16). Evaluation of Steelhead behaviors within the tailrace revealed the following observations:

1) Fish spent more time milling between the South Shore and Approach receivers along the south side of the tailrace compared to the north side of the tailrace, based on higher numbers of visits to the South Shore and Approach sites compared to the North Shore and Powerhouse North sites.
2) Fish visited the Approach site more than any other site in the trailrace, approximatly double the number of site visits from the next most visited site, the South Shore site.
3) Fish were frequently detected but spent the least amount of time at the Entrance site, likley a result of high flows through this area and no locatoins for fish to hold.
4) Once in the trap, fish spent the most time holding inside Pool 4 and Pool 2 based on the relativley high median residence times and low number of site visits at these sites.
5) Fish did not spend a large amount of time holding at the Powerhouse South or the Powerhouse North Sites based on low median residence time, low numbers of visits, and low total time spent at these sites.
6) Behavioural trends were generally similar between Naïve and Non-Naïve fish with both release groups using the south side of the tailrace more than the north side.
7) However, Naïve fish generally had lower median residence times in the tailrace but higher median residence times in the trap area compared to Non-Naïve fish.

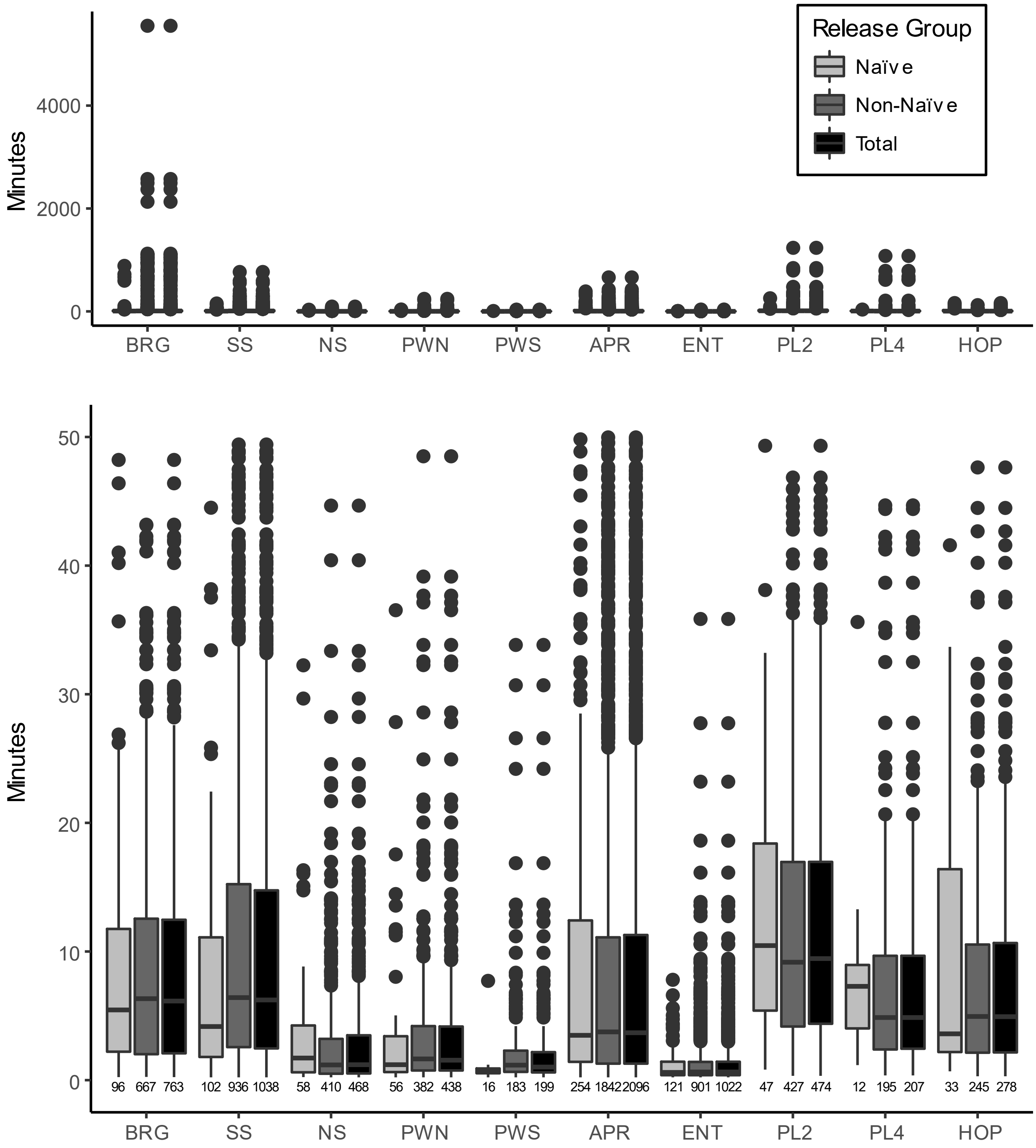

Figure 15. Median residence times by sites in the tailrace and trap. The top figure shows the full range of data, including outliers (closed circles), while the bottom figure zooms in to show the box and whisker plots, focusing on inter-quartile range. Data are separated by release group. Number of visits is displayed below boxplots. (*Caveat: these data are not scaled based on the detection ranges of each site.*)

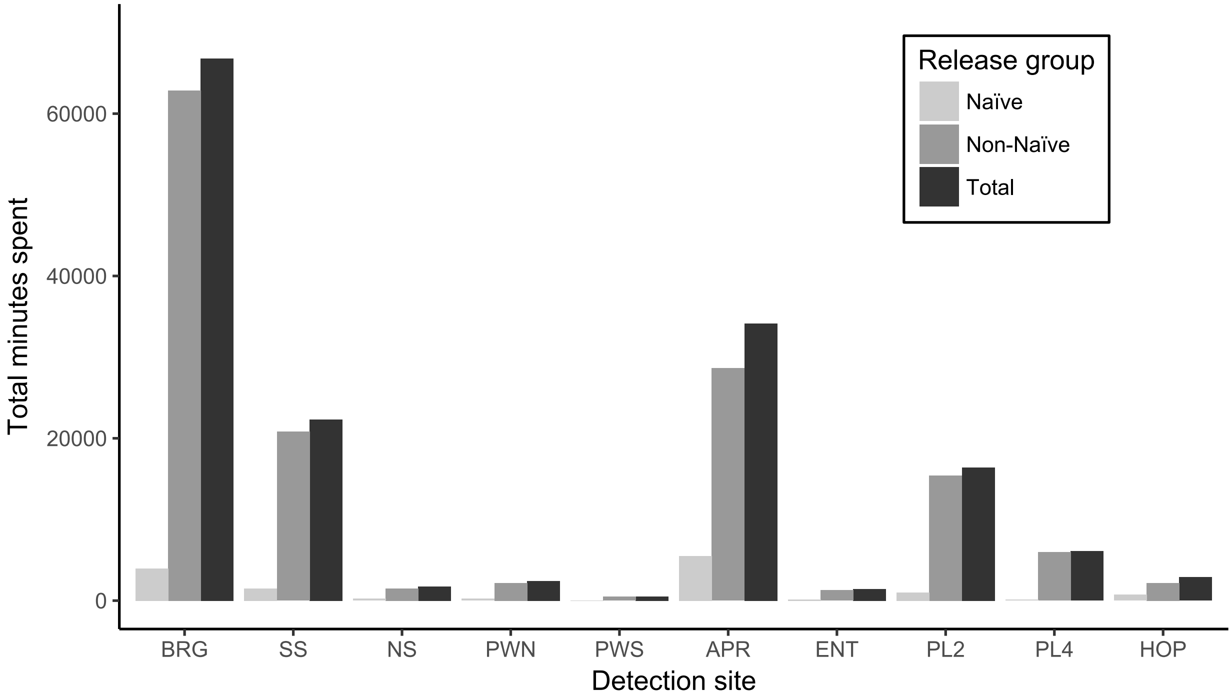

Figure 16. Total time spent by Steelhead in each site in the tailrace and trap. Data are separated by release group. Note: The Naïve release group had lower sample sizes than the Non-Naïve release group, therefore, direct comparisons of total time spent at each site between release groups is not appropriate. *Caveat: these data are not scaled based on the detection ranges of each site*.

Downstream behavior

At locations downstream of the tailrace, Non-Naïve fish held near the Lewis River Hatchery and Bed & Breakfast locations based on a low number of detections, high median residence, and total time spent at this location (Figure 17). Compared to Non-Naïve fish, Naïve fish held for less time at the Lewis River Hatchery, Bed & Breakfast and Boat Launch Downstream sites (Figure 17). Once upstream of the hatchery, individual fish did not hold station near the Boat Launch sites (Figure 17).

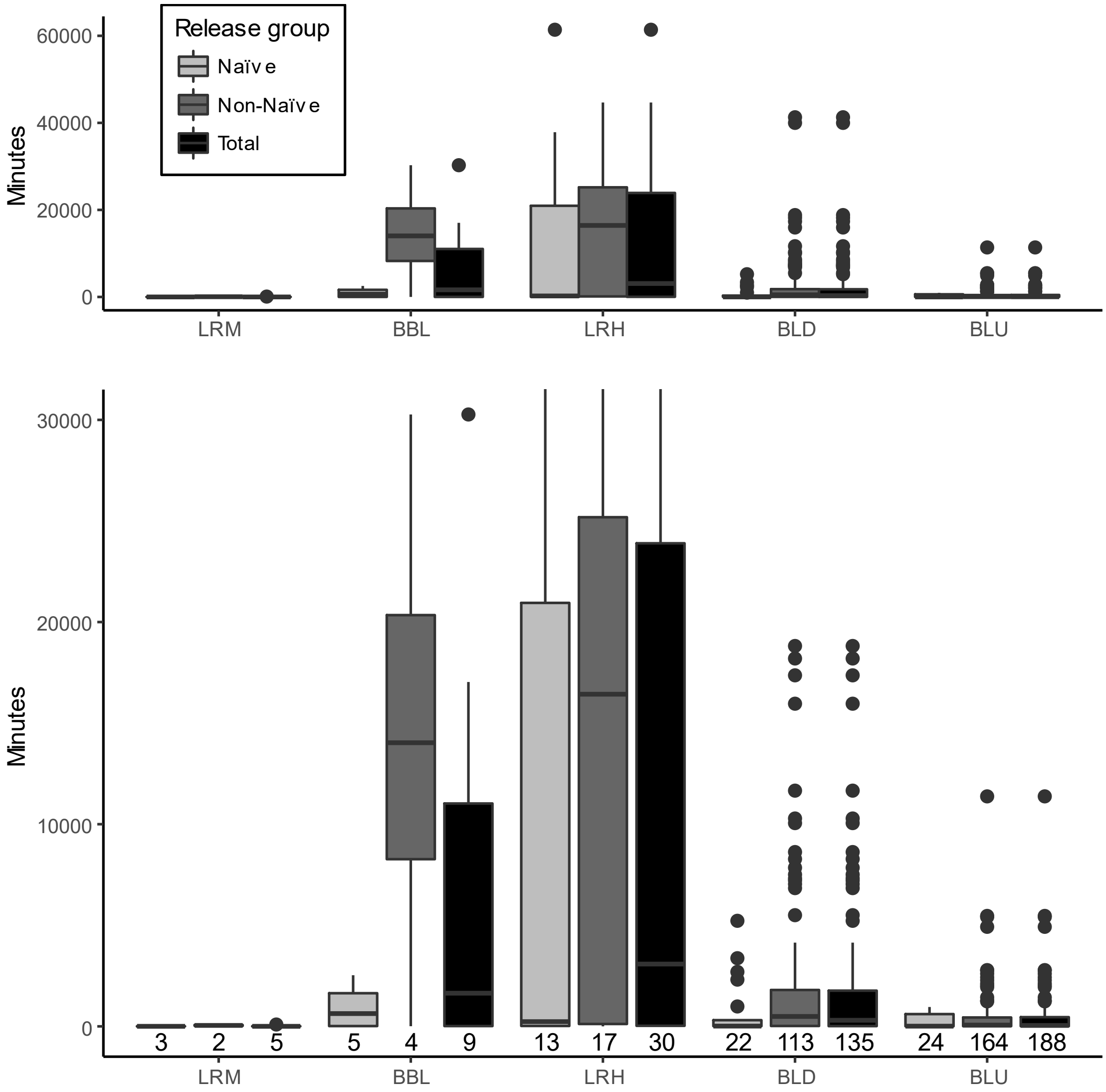

Figure 17. Median residence times for downriver sites. The top figure shows the full range of data, including outliers, while the bottom figure zooms in to show the box and whisker plots, focusing on inter-quartile range. Sample size (n) is displayed below the box plot for each site. *Caveat: these data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

Naïve fish spent the most time at the Lewis River Hatchery site (159,155 minutes or ~ 111 days; Figure 19), which was directly downtream from where most fish were released. The total amount of time Naïve fish spent at the Lewis River Hachery accounted 80% of the total time Naïve fish spent across all locations in the study area (i.e., including both tailrace and downstream sites).

Similarly, Non-Naïve fish also spent the largest amount of time at the site downstream from their release locaiton, the Boat Launch Downtream site (308,723 minutes or ~ 214 days; Figure 19). Non-Naive fish spent 36% of total time across all locatoins in the study area at the Boat Launch Downstream. In contrast, Naïve fish spent only 8% of their total time at the Boat Launch Downstream site.

Non-Naïve fish also spent a large amount of time (270,358 or ~ 188 days) at the Lewis River Hatchery site (Figure 19), which was 2 times greater than the amount of time spent in the tailrace (Non-Naïve fish spent a total of 141,255 minutes or ~ 98 days in the tailrace).

Within their respective release group, both Naïve and Non-Naïve fish spent the least amount of time at the Lewis River Mouth site followed by the Bed & Breakfast site (Figure 19).

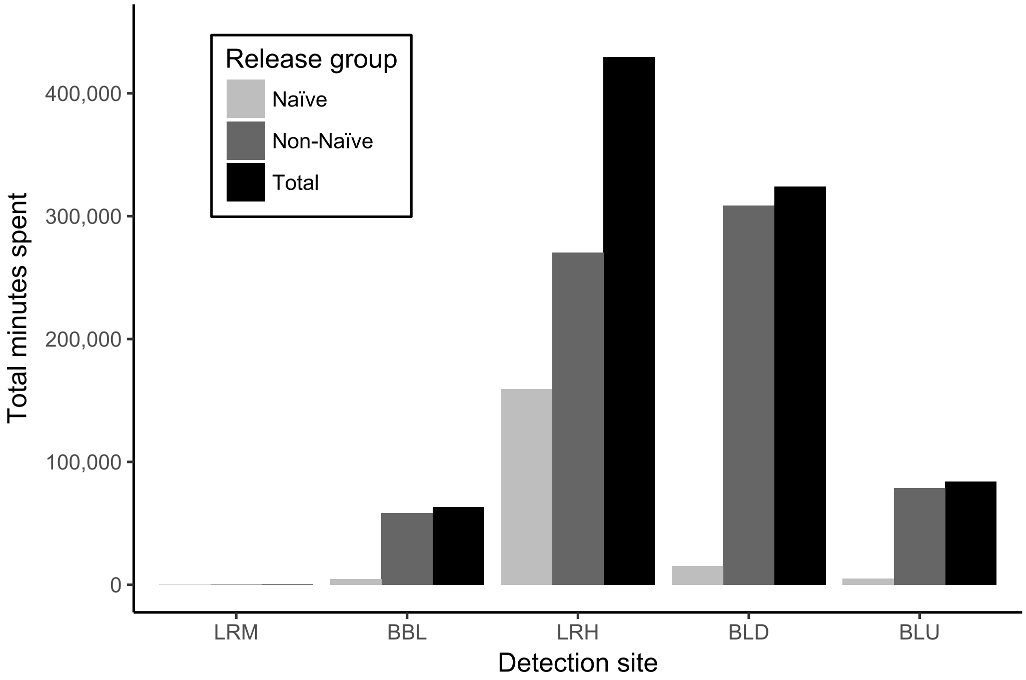

Figure 18. Total time spent by Steelhead in each downriver site. Data are separated by release group. The Naïve release group had lower sample sizes than the Non-Naïve release group, therefore, direct comparisons of total time spent at each site between release groups is not appropriate. *Caveat: these 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

The median tailrace residence time for all Steelhead (i.e., Naïve and Non-Naïve fish combined) in the Merwin Dam tailrace was 14.0 hours (range = 7 minutes – 219 hours) (Table 7). The upper end of this range may represent total time spent during multiple trips through the tailrace. Only three Steelhead (approximately 4% of the 77 fish that passed) exhibited tailrace residence time greater than 168 hours (all three of these Steelhead were Non-Naïve fish) (Table 7). Both Naïve and Non-Naïve fish had median tailrace residence times < 24 hours with < 5% of fish taking longer than 168 hours to pass (Table 7). Thus, performance standard compliance metrics for safe, timely, and effective passage were met for both Naïve and Non-Naïve fish.

Table 7. Achieved performance standard compliance metrics for safe, timely, and effective passage across four study years for three study species at Merwin Dam. Sample sizes (*N*) are for total number of fish tagged. In 2018, metrics are also presented separately for Naïve and Non-Naïve fish.

Study Year	Species/Release Group	*N*	Median Tailrace Residence (range)	Percentage of Fish with Tailrace Residence Time > 168 hrs
2015	Winter Steelhead	148	49.4 hrs (0.08-1,077.4 hrs)	14%
	Spring Chinook	40	246.5 hrs (0.01-1412.4 hrs)	65%
	Coho Salmon	35	15.3 hrs(0.21-395.7 hrs)	6%
2016	Winter Steelhead	148	29.2 hrs (0.03-605 hrs)	10%
	Spring Chinook	N/A	N/A	N/A
	Coho salmon	N/A	N/A	N/A
2017	Winter Steelhead	150	11.8 hrs (0.03-403 hrs)	7%
	Spring Chinook	N/A	N/A	N/A
	Coho salmon	149	5.6 hrs (0.03-192 hrs)	2%
2018	Winter Steelhead	92	14.0 hrs (0.12-219 hrs)	4%
	Naïve	*19*	*6.0 hrs (0.7-90.5 hrs)*	*0%*
	Non-Naïve	*73*	*19.8 hrs (0.12-219 hrs)*	*4%*

Additionally, the following results regarding tailrace residence times were apparent from evaluation of the detection data:

- Seven Steelhead (all Non-Naïve) entered the trap but were never captured.
    - These fish exhibited a median tailrace residence time of 32 hours (range = 3.0 – 219 hours), with none exhibiting a tailrace residence time >168 hours.
- Seventy-seven Steelhead entered the trap and were captured successfully.
    - These fish exhibited a median tailrace residence time of 14 hours (range = 0.6 – 187 hours), with two (3%) exhibiting a tailrace residence time >168 hours.

Statistical comparisons indicated Naïve fish had significantly lower median tailrace residence time compared to Non-Naïve fish (W=629, p = 0.031). On average, Naïve fish spent ~19 fewer hours in the tailrace prior to being recaptured compared to Non-Naïve fish (Figure 19).

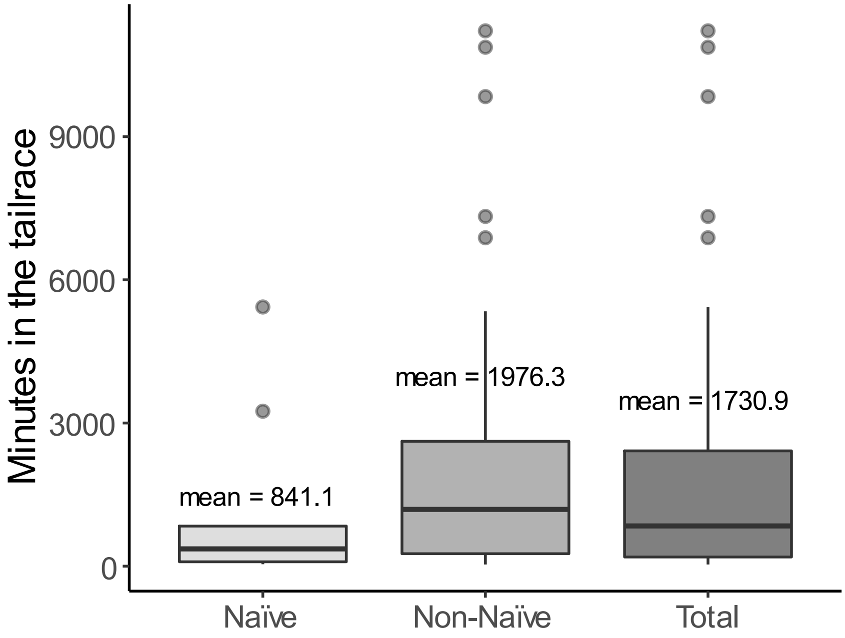

Figure 19. Boxplot showing the number of minutes in the tailrace prior to passing for Naïve and Non-Naïve fish.

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 facilitate comparisons with previous reports and ease of interpretation, we present Objective 5 results separately for Non-Naïve fish, which are comparable to results from previous studies, and for Naïve fish.

Non-Naïve fish

All of the 73 tagged Non-Naïve fish were detected somewhere in the study area, and thus had radio detection data available to describe movements downstream of the final Trap receiver. The following inferences can be made on the movements of these 73 fish with detection data available, but it should be noted that the numbers presented below do not account for tag sheds and, therefore, do not correspond to those presented in Table 3 above. Also, the groups below represent intersecting (not mutually exclusive) sets, and thus do not sum to 73.

Of the 73 Non-Naïve fish detected somewhere in the study area:

- 67 fish (92%) were detected somewhere in the tailrace. Of these 67 fish detected somewhere in the tailrace,
    - 36 fish (54%) returned to downriver sites (i.e., below the access bridge); 29 of these 36 (81%) were eventually successfully captured while the remaining 7 fish were not.
    - A total of 66 fish (99%) were detected somewhere in the trap ladder system. Of these 66 fish that were detected in the trap ladder,
        - 48 fish (72%) returned to the tailrace after first visiting the trap; 14 of these 48 fish never made it further than the Entrance before exiting (i.e., 14 fish never passed the fyke before exiting the trap ladder).
        - Of those 48 fish that moved back downstream (into the tailrace) after their first post-tagging encounter with the trap,
            - 41 fish (85%) were eventually captured; the remaining 7 fish were not.
        - Approximately 26% of fish that entered the trap (17 of 66) continued through and were captured on their first post-tagging encounter with the trap.
- 12 fish (16%) were not re-captured but were detected somewhere in the study area. Of those 12 fish,
    - One fish was last detected at the furthest downstream site, the Lewis River Mouth (
    - **Note**: The fate of fish that failed to be trapped cannot be confirmed. For example, fish last detected at the Boat Launch Downstream site could have died somewhere in the system between this site and downstream sites or could have experienced tag failure or tag regurgitation following detection at this site.

  - **Table 8**), and eight fish were last detected at the Boat Launch Downstream site (
  - **Note**: The fate of fish that failed to be trapped cannot be confirmed. For example, fish last detected at the Boat Launch Downstream site could have died somewhere in the system between this site and downstream sites or could have experienced tag failure or tag regurgitation following detection at this site.

  - **Table 8**).
  - Note: The fate of fish that failed to be trapped cannot be confirmed. For example, fish last detected at the Boat Launch Downstream site could have died somewhere in the system between this site and downstream sites or could have experienced tag failure or tag regurgitation following detection at this site.

Table 8. Last known location for the 12 fish that were not re-captured but were detected somewhere in the telemetry array.

Site of Last Detection	n
Lewis River Mouth	1
Bed & Breakfast	2
Lewis River Hatchery	1
Boat Launch Downstream	8
Total	**12**

Naïve fish

All of the 19 tagged Naïve fish were detected somewhere in the study area, and thus had radio detection data available to describe movements downstream of the final Trap receiver. The following results were apparent regarding the movements of these 19 fish with detection data available, but it should be noted that the numbers presented below do not account for tag sheds and, therefore, do not correspond to those presented in Table 3 above. Also, the groups below represent intersecting (not mutually exclusive) sets, and thus do not sum to 19.

Of the 19 Naïve fish detected somewhere in the study area:

- 16 fish (84%) were detected somewhere in the tailrace. Of these 16 fish detected somewhere in the tailrace,
    - Zero fish (0%) returned to downriver sites (i.e., below the access bridge) prior to being captured.
    - A total of 16 fish (100%) were detected somewhere in the trap ladder system. Of these 16 fish that were detected in the trap ladder,
        - Zero fish (0%) returned to the tailrace after first visiting the trap.
- Three fish (16%) were not re-captured but were detected somewhere in the study area. Of those three fish,
    - Two were last detected at the Lewis River Mouth site and one was last detected at the Boat Launch Downstream site.

Objective 6: Determine the condition of Steelhead that are captured by the trap, as a function of individual fish energetic state, and rates of descaling, injury, and reflex impairment.

Condition of Steelhead prior to release was evaluated by measuring muscle lipid content (i.e., energetic state) of fish and assessing reflex impairment using RAMP protocol (see Methods for additional details on measuring energetic state and RAMP).

Fish energetic state

The percent muscle lipid content of fish used in the study ranged from 0.9 – 4.1 % (mean ± SD = 1.9 ± 0.8 %). There was a significant negative relationship between tagging date and muscle lipid content of fish (df = 86; $p = 0.007$); the trend indicating fish tagged later in the study had lower muscle lipid content compared to fish tagged earlier in the study (Figure 20). However, release date explained only a small amount of the variability in muscle lipid content (adjusted $R^2 = 0.07$). Naïve fish exhibited significantly lower measured muscle lipid content than Non-Naïve fish (df = 86, $p = 0.024$).

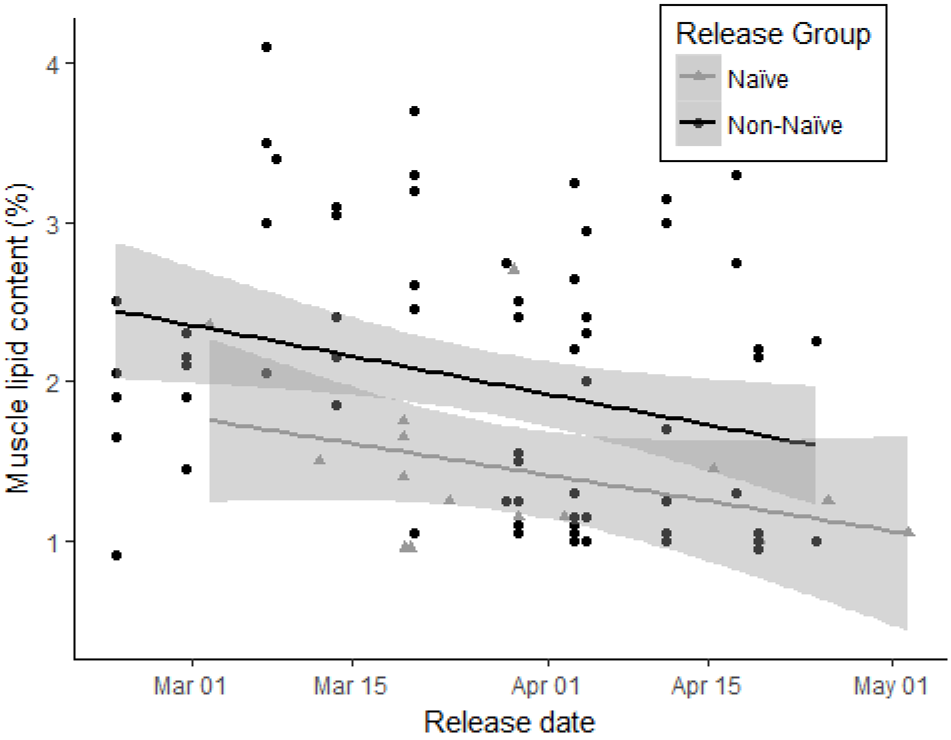

Figure 20. Muscle lipid content of individual Steelhead by release date. Shading and symbols indicate individual fish release group (Naïve = grey, triangles; Non-Naïve = black, circles). Lines are based on linear regression and shaded areas around lines represent 95% confidence intervals in the fit.

Comparisons of muscle lipid content between trapped and not trapped fish indicated trapped fish had significantly higher muscle lipid content compared to fish that were not trapped ($W = 331.5$, p = 0.033) (Figure 21). On average, trapped fish had 0.3% greater muscle lipid content compared to fish that were not trapped.

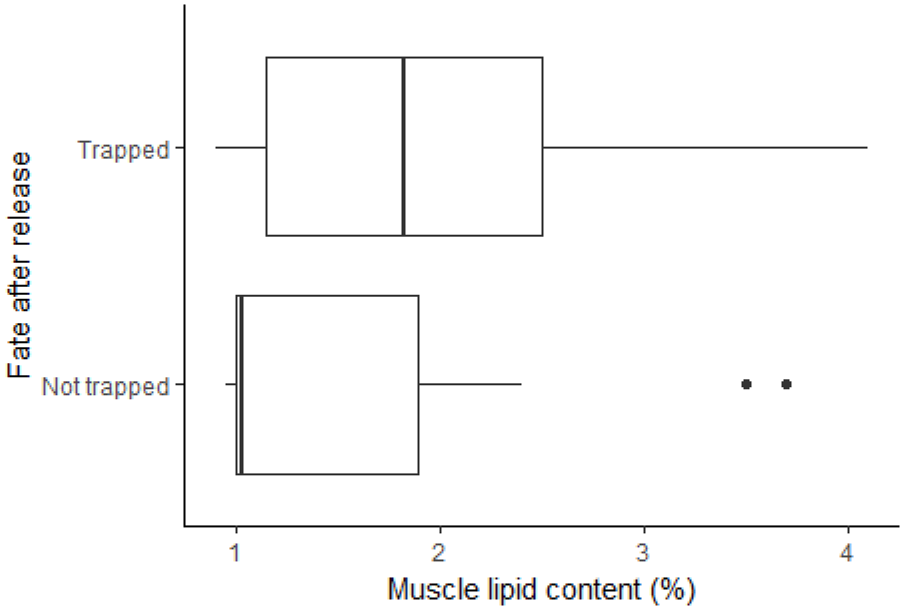

Figure 21. Box and whisker plot of the muscle lipid content of fish that were trapped versus fish that were not trapped at the Merwin Fish Collection Facility after release.

Reflex impairment

Impairment of five different reflexes was assessed for 92 fish before they were released. Of these 92 fish:

- 87 (95%) had zero impaired reflexes out of the five reflexes assessed.
- Five (5%) fish had one or more reflexes impaired; two of these fish had two reflexes impaired and three fish had one reflex impaired.
- The two fish with more than one reflex impaired were initially captured by tangle netting.
- All (100%) of fish with one or more reflex impaired were eventually captured at the Merwin Fish Collection Facility after release.

Low variability of reflex impairments among fish limited the ability to statistically test for differences in reflex impairment between fish that were trapped versus not trapped after release.

OTHER

Only re-captured radio tagged fish were included in the injury assessment, because including maiden captured fish in injury assessments would be problematic, as, prior to being trapped, fish have traveled long distances and are subject to other sources of injury that cannot be separated from those caused by trapping operations. Only healthy Steelhead free of injury were tagged in the study. Once a radio tagged fish was re-captured, it was then inspected for injury and any found injuries were assumed to be caused by trapping effects.

No injuries were observed on any of the fish that were recaptured at Merwin Fish Trap. However, one mortality was observed of the 77 recaptured. It was therefore determined that there was an observed injury rate of 0%, and a transport survival rate of 98.7% for Steelhead in 2018.

Objective 7: Continue to assess environmental conditions as they relate to interannual differences in *ATE*.

Total NF Lewis River discharge in 2018 was initially high (> 10,000 cfs) at the start of tagging in February, but quickly decreased to less than 5,000 cfs by mid-February (Figure 22). Flow remained fairly low and consistent until early April when flow increased to greater than 10,000 cfs in mid-April, but then decreased again by May and remained fairly low and consistent over the remainder of the study (Figure 22).

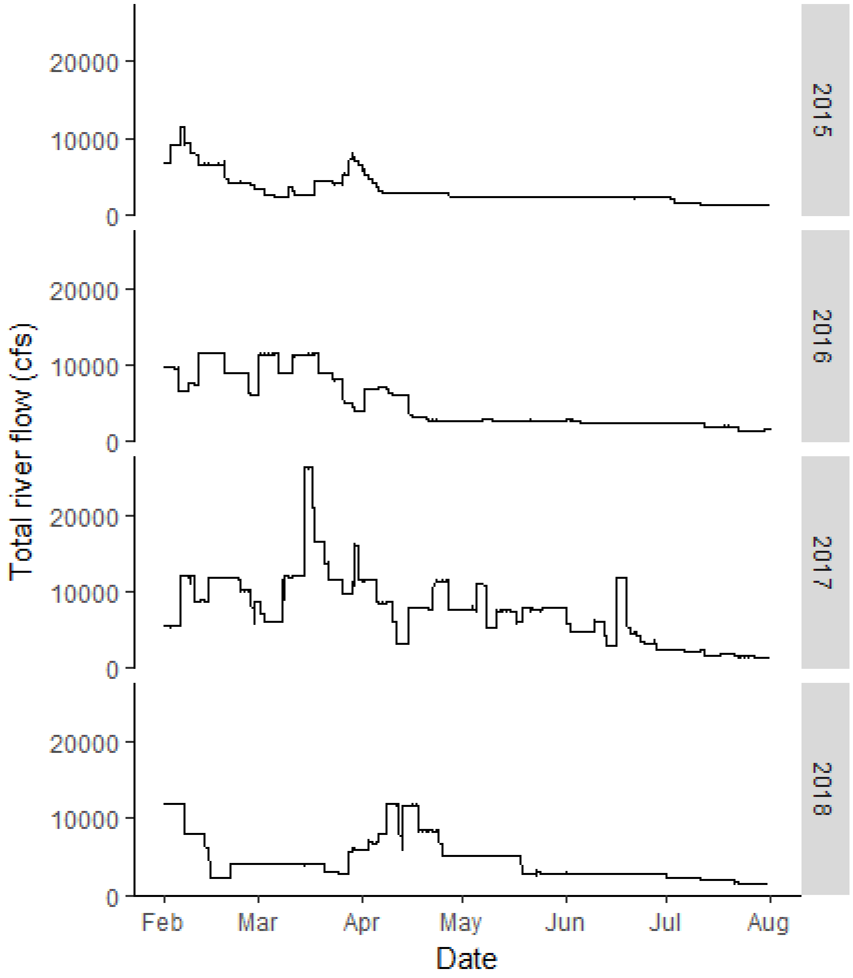

Figure 22. NF Lewis River discharge (cfs), measured downstream of Merwin Dam during Steelhead monitoring across 4 study years.

Interannual comparisons indicate that, in 2018, mean total NF Lewis River discharge was generally lower compared to 2017 (~60% lower), higher compared to 2015, and similar to 2016 (Table 9). The trends in total NF Lewis River discharge over the study season in 2018 were most similar to that in 2015 (Figure 22).

Table 9. Summary statistics for total NF Lewis River discharge (cfs) and Winter Steelhead core metrics (P_{EE} and ATE_{test}) across 4 study years. Only Non-Naïve fish are included in 2018 to ensure core metrics are comparable with those from previous study years. Note that to estimate 95% confidence intervals (CI), 2018 used Bayesian Credible Intervals, whereas all other study years used bias-corrected and accelerated methods.

Study Year	**mean (±sd) Total River Flow (cfs)**	**range (min-max) Total River Flow (cfs)**	**Species**	***N***	***Raw P_{EE} (95% CI)***	***Raw ATE_{test} (95% CI)***
2015	3229 (±1924)	1060-11400	Winter Steelhead	148	86% (79-90%)	61% (51-67%)
2016	4905 (±3372)	1260-11600	Winter Steelhead	148	93% (87-96%)	73% (65-80%)
2017	7476 (±4337)	1190-26200	Winter Steelhead	150	84% (77-90%)	76% (70-84%)
2018	4556 (±2838)	1518-11900	Winter Steelhead	73	99% (92-100)	91% (83 – 96%)

DISCUSSION

This report focuses on BWT hatchery Winter Steelhead collected and tracked during 2018, the fourth year of CFS reporting Steelhead movements and passage metrics at Merwin Dam. Of note, this fourth study year compared core passage metrics and movements of two release groups:

- Fish captured at the Merwin Fish Collection Facility and subsequently released downstream (i.e., trap Non-Naïve fish). This group is most similar to groups of fish collected in previous study years.
- Fish captured, tagged and released downstream from Merwin Dam, and thus presumably had no prior encounter with the trap (i.e., trap Naïve fish).

This was the first study year to include a trap Naïve release group of fish; all previous study years used fish collected from the trap (i.e., Non-Naïve) to assess passage efficiency as Merwin Dam.

In 2018, a total of 92 Steelhead were tagged including 73 Non-Naïve fish and 19 Naïve fish.

Of all 92 fish:

- 92 were detected at least once somewhere within the detection array;
- 83 entered the tailrace of Merwin Dam (M);
- 82 entered the trap (C), resulting in a raw P_{EE} $(\frac{C}{M})$ of 99%; and
- 77 were successfully captured (T), resulting in a raw ATE_{test} $(\frac{T}{M})$ of 93%.
- The Bayesian posterior estimate of ATE_{test} for all fish was 92% (95% HDI = 85 – 97%).

Of the 73 Non-Naïve fish:

- 73 were detected at least once somewhere within the detection array;
- 67 entered the tailrace of Merwin Dam (M);
- 66 entered the trap (C), resulting in a raw P_{EE} $(\frac{C}{M})$ of 99%; and
- 61 were successfully captured (T), resulting in a raw ATE_{test} $(\frac{T}{M})$ of 91%.
- The Bayesian posterior estimate of ATE_{test} for Non-Naïve fish was 90% (95% HDI = 83 – 96%).

Of the 19 tagged Naïve fish:

- 19 were detected at least once somewhere within the detection array;
- 16 entered the tailrace of Merwin Dam (M);
- 16 entered the trap (C), resulting in a raw P_{EE} $(\frac{C}{M})$ of 100%; and
- 16 were successfully captured (T), resulting in a raw ATE_{test} $(\frac{T}{M})$ of 100%.
- The Bayesian posterior estimate of ATE_{test} for Naïve fish was 96% (95% HDI = 84 – 100%).

When considering either all fish together or the subset of Non-Naïve fish, both groups exhibited ATE_{test} values that were statistically credibly below performance standards. Moreover, when considering all fish together, there was less than 0.2% posterior probability that that the true *ATE* of the parent population of Winter Steelhead (i.e., fish that were both trap naïve and those that had previously been captured) met the 98% performance standard for fish passage. This probability was even lower (i.e., <0.1%) when only considering Non-Naïve fish, the group most similar to fish included in previous years, which includes only fish that had previously been captured. However, when considering Naïve fish only, there was a 29% posterior probability that the true *ATE* of the parent population of Winter Steelhead (i.e., fish that had not been previously captured) was equal to or greater than the 98% performance standard. Thus, it is not credible that the parent population of BWT hatchery Winter Steelhead in the NF Lewis River truly exhibited $ATE \geq ATE_{target}$ in 2018. However, it should be noted that raw ATE_{test} values measured in 2018 were the highest ATE_{test} values among all study species examined across all four years evaluating *ATE* at Merwin Dam (although significance or credibility of this difference was not evaluated).

Although *ATE* performance standards were not met for Non-Naïve fish, and there is uncertainty about *ATE* performance standards being met for Naïve fish in 2018, performance standards for tailrace residence time were met for both release groups of fish. Median tailrace residence time for Non-Naïve fish (including both re-captured and not re-captured fish) in 2018 was 19.8 hours, which is less than the regulatory standard of 24 hours. In addition, only 4% of Steelhead in 2017 took longer than 168 hours to pass, which is less than the regulatory standard of 5%. Compared to Non-Naïve fish, tailrace residence times were 19 hours less on average for Naïve fish. Lower tailrace residence times of Naïve fish suggest Naïve fish exhibit more direct movements in the tailrace compared to Non-Naïve fish and is additional evidence for behavioral differences between Naïve and Non-Naïve fish.

In 2018, Steelhead located and entered the trap from the tailrace (P_{EE}) at the highest observed rate among all species and study years. Raw P_{EE} was 99% and 100% for Non-Naïve and Naïve fish, respectively in 2018 (the highest raw P_{EE} values observed prior to 2018 was 93% in 2016). Thus, under a hypothetical scenario where all fish that entered the trap were successfully captured, raw ATE_{test} in 2018 would have achieved the performance standard of 98% for both Non-Naïve and Naïve fish. For the first time across all study years, retention in the trap, rather than attraction to the trap, appeared to be the primary factor limiting Steelhead passage in 2018.

Despite raw P_{EE} being high in 2018, it was still lower than the rate at which fish were recaptured (raw ATE_{test} = 91%), which is consistent with findings in previous study years. This observation is reflected by a raw trap ineffectiveness (T_i) of 6% for 2018, which slightly lower than values reported in 2017 (9%) and the lowest value reported among study years. Reduced T_i for 2018 (and 2017) was likely the result of a fyke that was installed within the trap ladder prior to the 2017 tagging study. Results from 2017 indicated the fyke was highly effective and reduced the number of trap exit events by 98% compared to 2016 (before the fyke was installed) (Drenner et al. 2018a). In 2018, approximately 50% of the fish that entered the trap later exited, which was lower than the percentage of fish that exited in 2016 (96%) but higher than in 2017 (25%). NF Lewis River discharge was higher in 2017 compared to 2018, and when Lewis River discharge is high, it can ‘back up’ into the trap ladder thereby decreasing flow in the trap ladder. We propose that high NF Lewis River stage that reduces outflow in the trap ladder could increase fyke effectiveness because it reduces the ability of fish to detect directionality of flow and locate the exit through the fyke, which may explain the differences in trap exit events between 2017 and 2018. Interestingly, data in 2017 indicated that high NF Lewis River discharge was associated with more fish exiting the fyke. Increased exit events during high flow in 2017 was through to be due to fish exiting through an opening at the top of the fyke that became exposed during high flow events. Of note, in the current year, none of the Naïve fish exited the trap before being recaptured.

Steelhead in 2018 appeared to be generally attracted to the tailrace and trap, potentially more so than observed in pervious study years. Evidence to support this is summarized below:

1) High probabilities of fish moving upstream from sites below the tailrace except for the Bed & Breakfast and Lewis River Mouth sites.
2) Approximately 90% of the total number of released fish (83/92) were detected entering the tailrace.
3) After entering the tailrace, Steelhead most frequently took a path along the south side of the tailrace where navigational cues are presumably present to lead fish to the trap entrance.
4) Based on the network analysis, the path that most frequently led to detection at the Approach site was from the South Shore site.
5) As described above, almost all fish (99%) that entered the tailrace entered the trap based on high P_{EE} estimates in 2018, which were the highest among all study years.

Overall, fish appeared to be more attracted to the tailrace and trap compared to previous years, which likely contributed to the highest raw ATE_{test} values being observed in 2018 among all study years. The increased attraction to the trap and high ATE_{test} values observed in 2018 could be related to a variety of factors including infrastructure and operations (e.g., addition of fyke to trap ladder), environmental conditions (e.g., NF Lewis River discharge) and internal fish status (e.g., energetic and physiological state). For example, as described above, the fyke installed in 2017 reduced the number of fish exiting the trap, and thus could contribute to increased ATE_{test} values observed for Steelhead in 2017 and 2018 compared study years before the fyke was installed. However, other factors must be contributing to higher ATE_{test} observed in 2018 compared to 2017 because the fyke was present in the trap ladder in both years.

Total NF Lewis River discharge was proposed as a variable that could influence *ATE* at Merwin Dam. Data exploration using three years of data (2015-2017) indicated fewer trap entrance attempts during higher NF Lewis River discharge, especially when NF Lewis River discharge exceeded 8,000 cfs (Drenner et al. 2018a). In 2018, NF Lewis River discharge was the second lowest among study years and *ATE* was the highest suggesting there could be a relationship between high *ATE* in 2018 and NF Lewis River discharge. However, it should be noted that these relationships are observational; additional data analysis would be needed to better understand the influence of NF Lewis River discharge on *ATE* at Merwin Dam.

Internal fish factors such as energetic state, reproductive maturity and stress could also contribute to *ATE* differences among study years. In 2018, individual fish muscle lipid content (indicator of fish energetic state) was measured prior to release. Energetic state of fish arriving in the study area is influenced by factors fish encountered during previous life stages, and therefore is indicative of a baseline condition of fish. Steelhead in our study had muscle lipid content within the ranges reported for Steelhead nearing spawning in other studies (Pierce et al. 2017). Comparisons of muscle lipid content of fish that were successfully trapped versus fish that were not trapped indicated fish with lower energy reserves were less likely to be recaptured following release, which coincides with previous studies that showed homing salmonids with lower energy reserves had reduced migration success compared to fish with higher energy reserves (Crossin et al. 2009).

Steelhead that were eventually trapped had 0.3% higher muscle lipid content compared to fish that were not captured. For context, a previous study showed differences of 0.5% following 5- to 8-week ration restriction in rainbow trout, and these differences paralleled differences in reproductive maturation trajectory (Caldwell et al. 2017). Thus, a difference of 0.3% appears biologically relevant, especially during final stages of reproductive maturation. Additionally, we detected decreasing energy reserves of fish captured over the course of the study, which is expected and could explain observations of decreasing ATE_{test} by release date in previous study years (cf. Drenner et al. 2018b). Lower energy reserves could indicate these fish were less able to acquire resources; used energy inefficiently; encountered conditions that reduced energy such as higher water temperatures; or may have invested more energy into gonadal development (i.e., they may be more reproductively mature). Any of these factors associated with reduced energy could make a fish less likely to expend energy migrating upstream and instead may be more likely to spawn in areas downstream of Merwin Dam.

Stress levels of individual Steelhead were assessed in addition to energetic state in 2018. In previous studies, migrating salmonids with signs of high stress levels were shown to have slower migration times and reduced migration success (Cooke et al. 2006), and acute stress levels from capture and handling as indicated by impaired reflexes have been shown to be a predictor of post-release survival (Davis 2010; Raby et al. 2012). In this study, few fish showed reflex impairments prior to release, and thus stress from capture and handling was unlikely to influence post-release behavior and passage success. Interestingly, the greatest amount of time spent after release for Naïve and Non-Naïve fish was at receivers located immediately downstream of their respective release sites. For example, following release, Non-Naïve fish spent 36% of their total time at the Boat Launch Downstream site located approximately 0.25 km downstream of the release location, and Naïve fish spent 80% of their total time at the Lewis River Hatchery site, which was located approximately 0.5 – 5 km downstream from the majority of tangle netting locations where Naïve fish were captured and released (three Naïve fish were tagged and released downstream from the Lewis River Hatchery site). The large amount of time spent at these downstream receivers does suggest some amount of recovery experienced by fish following capture and handling, but our evaluation of reflex impairments suggest the level of stress is minimal, similar among release groups of fish and not likely to influence our results.

It was proposed, based on tag recoveries in neighboring tributaries, that straying could influence *ATE* estimates at Merwin Dam. To investigate straying rates, three additional telemetry sites were installed in 2018 on Cedar Creek and the East Fork Lewis River (two tributaries to the Lewis River where straying is suspected) and at the mouth of the Lewis River (used to assess fish exiting the system into the Columbia River). There were no fish detected on either Cedar Creek or the East Fork of Lewis River telemetry sites and only five fish were detected on the telemetry site at the mouth of the Lewis River; three of these five fish were last detected at the mouth of the Lewis River suggesting those fish may have exited the system (or were mortalities that passively drifted downstream). Additionally, fish in 2018 had high rates of transitioning forward from sites downstream of the tailrace suggesting fish were attracted to the tailrace. Overall, it appears straying rates were minimal and attraction to the tailrace was high in 2018, which could contribute to higher observed *ATE*.

Comparisons between Naïve and Non-Naïve fish

Raw ATE_{test} values were greater for Naïve fish (raw ATE_{test} = 100%) than for Non-Naïve fish (raw ATE_{test} = 91%) in 2018. Statistical analyses used to compare ATE_{test} between Naïve and Non-Naïve fish indicated an 80% posterior probability that Naïve fish exhibited 5% greater *ATE* compared to Non-Naïve fish. While this probability does not pass standard 95% credibility standards, the effect size for the difference in ATE_{test} between Naïve and Non-Naïve fish (5%) at this confidence level (80%) are promising and warrant follow up. Precision and confidence in posterior estimates of ATE_{test} and effect size between groups could be improved by increasing sample sizes of the Naïve release group in future studies.

In addition to observed differences in ATE_{test} between Naïve and Non-Naïve fish, multiple additional lines of evidence suggests there were biological differences between these two groups and how they moved through the study area. Evidence in support of differences between Naïve and Non-Naïve fish include:

1) Despite being released further downstream from the dam tailrace than Non-Naïve fish, Naïve fish visited significantly fewer sites (31 fewer sites on average) before being recaptured compared to Non-Naïve fish.
2) Naïve fish generally had higher probabilities of moving forward from sites within the tailrace and trap, as well as at sites directly downstream of the tailrace.
3) Zero Naïve fish left the tailrace after entering, and zero Naïve fish left the trap after entering. In contrast, 54% of Non-Naïve fish left the tailrace after entering and 50% of the Non-Naïve fish left the trap after entering.
4) Naïve fish had significantly lower residence times (19 hours less on average) in the tailrace compared to Non-Naïve fish.

A third release group was also included in 2018 that consisted of Naïve fish that were recaptured at the Merwin Fish Collection Facility and then released downstream at the Merwin Boat Launch making these fish similar to Non-Naïve fish; the major difference being these fish had been captured and handled twice, once during tangle netting and then again when recaptured at the trap. This third release group (referred to as Non-Naive$_2$) is a subset of the trap-Naïve fish; consequently, they were not included in any data analysis due to low sample sizes (n=7) and the use of repeated measures if these fish were included in core passage metric estimates (i.e., these fish would be included as both Naïve and Non-Naive$_2$ release groups). Regardless, the Non-Naive$_2$ release group can provide insights into performance of fish locating and entering the fish trap a second time. Compared to first attempts at locating and entering the trap (i.e., when they were Naïve fish), during the second attempts, Non-Naive$_2$ fish:

1) Entered the tailrace at lower proportions after release (71% compared to 84% as Naïve fish) despite being released closer to the tailrace.
2) Entered the trap from the tailrace at lower proportions (P_{EE} = 80% compared to P_{EE} = 100% as Naïve fish).
3) Were recaptured after entering the tailrace at lower proportions (ATE_{test} = 80% compared to ATE_{test} = 100% as Naïve fish).
4) Exited the trap at higher proportions; four out of five fish (80%) exited the trap after entering (none of these fish exited the trap during their first encounter with the trap).
5) Visited approximately twice as many sites on average before being trapped.

6) Spent approximately 2.5 additional hours on average in the tailrace prior to being trapped.

It appears that ATE_{test} decreased across release groups in the order: Naïve > Non-Naïve > Non-Naive$_2$. Given the strength of these relationships, a moderate amount of confidence in this ordering can be inferred. While the strength of this confidence falls short of providing convincing evidence, these results do warrant follow up and further evaluation to confirm or refute this initial perception. In addition, these preliminary results suggest a hypothesis regarding the underlying general phenomenon of recapture likelihood following handling. The fact that the ordering of ATE_{test} (Naïve > Non-Naïve > Non-Naïve$_2$) mirrors the amount of handling experienced by these groups suggests a cumulative effect of handling on the reduction of recapture rate. That is, fish that were tangle netted only once then released (Naïve) exhibited the greatest ATE_{test}. Fish that located the trap and were captured, trucked, then released—a potentially more substantial "handling" experience than being captured and released within a period of minutes—exhibited slightly lower ATE_{test}, but similar P_{EE}. This seems to suggest that this group had no problem finding the trap, but that upon navigating the reach below the dam and locating the trap entrance, may have "decided" not to continue into the trap infrastructure, potentially reflecting the aversive nature of the experience and their resulting operant conditioning. Finally, fish that were tangle netted, released, navigated to the trap, then were collected, trucked, and released downstream—the Non-Naïve$_2$ group, certainly the most invasive of the three treatments—exhibited the lowest rate of return to the trap entrance (P_{EE}) and subsequent recapture (ATE_{test}). Evaluating these Non-Naïve$_2$ results in the context of the other groups further supports such operant conditioning, particularly in light of what appears to be a dose-dependent effect size. However, it bears repeating that the small and very small sample sizes of the Naïve and Non-Naïve$_2$ groups hinders confidence in these results. Thus, to reiterate, we stress that these findings should be treated as preliminary but do offer compelling evidence that such patterns and underlying phenomena should be investigated further.

Overall, multiple lines of evidence suggest that fish attempting to locate and enter the trap for a second time were less direct in their movements towards the trap and were less likely to be trapped than during their first attempt. These inferences support our prediction that fish naïve to the trap would have increased success of being recaptured at the Merwin Fish Collection Facility compared to fish that were previously captured by the trap. This prediction was based on previous studies that showed salmon have lower rates of successful dam passage after they have already ascended fishways and attempt to reascend a second time (Boggs et al. 2004; Burnett et al. 2014). In one study, Burnett et al. (2014) showed that Sockeye Salmon captured and released from a fish fence below a dam (i.e., dam naïve fish) were 15% more likely to locate and enter the fishway, had 16% greater passage success, and had shorter residence time in the dam tailrace compared to fish that were captured from the top of the fishway and released below the dam (i.e., dam non-naïve fish). Our findings support findings from previous studies and imply that current estimates of *ATE* at Merwin Dam using Non-Naïve fish are biased low. Additional studies that compare Naïve and Non-Naïve fish would help resolve differences between these two groups of fish.

CONCLUSIONS

In 2018, raw estimated adult trap efficiency (ATE_{test}) of the Merwin Dam Fish Trap Facility for all tagged Steelhead was 93% (BCI 95% CI = 85-97%), which is credibly below the performance standard of 98%.

The Merwin Dam Fish Trap Facility did achieve the performance standards for median tailrace residence time of less than or equal to 24 hours (median = 14 hours for Steelhead in 2018) and for less than or equal to 5% of fish taking longer than 168 hours to pass (4% of fish took longer than 168 hours to pass for Steelhead in 2018).

Estimated raw ATE_{test} and raw P_{EE} in 2018 for Steelhead was the highest across all three species and four study years examined to date.

Estimated raw P_{EE} in 2018 for Steelhead was 99%, and thus, if all fish that entered the trap were successfully collected in 2018, raw ATE_{test} values would have achieved the performance standard.

Elevated trap inefficiency (T_i) in 2018 versus 2017 is the result of fish exiting the trap through a fyke installed in 2017.

Although the fyke appears to reduce exit events from the trap compared to before the fyke was installed, we hypothesize that the fyke is less effective when NF Lewis River discharge is low (as was the case in 2018) because it creates greater flows in the trap ladder that provide fish a cue to locate the exit point through the fyke.

Steelhead were strongly attracted to the tailrace and trap in 2018 as evidenced by: high ATE_{test} and P_{EE}; none of the tagged Steelhead entered either tributaries suspected of attracting stray; and few fish were detected in the lower Lewis River sites.

Fish that were successfully recaptured had higher muscle lipid content (i.e., energy reserves) compared to fish that were not recaptured, which indicates background fish condition (e.g., reproductive maturation) or conditions encountered in previous life stages (e.g., ocean productivity) influences capture success.

ATE_{test} values were lower for fish tagged and released after being previously captured at Merwin Dam (i.e., Non-Naïve fish; raw ATE_{test} = 91%) compared to fish that had not previously encountered the dam (i.e., Naïve fish; raw ATE_{test} = 100%). However, these differences were not credibly different, likely a result of small sample sizes of Naïve fish.

Additional evidence suggested Naïve fish exhibited more direct movements towards the tailrace and trap. Compared to Non-Naïve fish, Naïve fish visited significantly fewer sites, spent significantly less time in the tailrace, and had higher probabilities of transitioning forward through the study area.

We recommend continuing to include and compare trap Naïve and Non-Naïve fish in future evaluations of *ATE*, and monitoring how river discharge effects trap retention.

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APPENDIX A: SUPPLEMENTARY INFORMATION

A-1 Radio antennas technical information

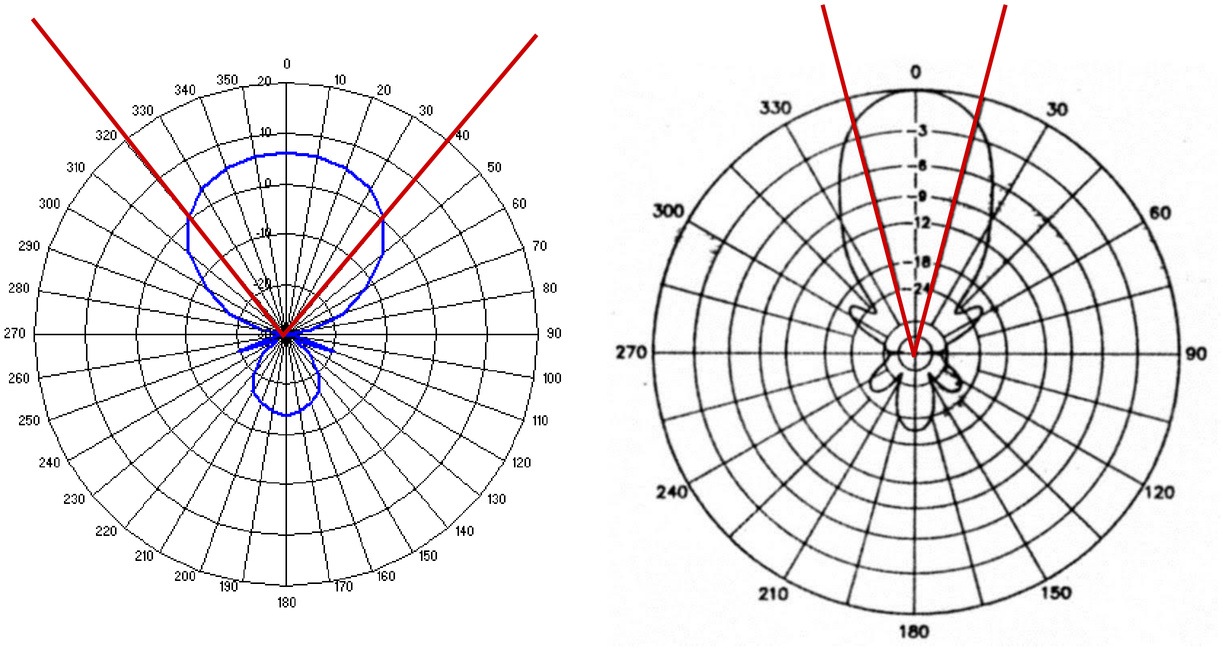
Five types of antennas were used during the 2018 Merwin *ATE* study: 3-, 6-, and 8-element aerial antennas, and underwater antennas. We describe the use and locations of these four antenna types below, with additional details provided in Table 2 above. *Three-element Yagi antennas* – Three-element antennas have a 6 dBd gain increase, the smallest dBd gain of the three Yagi-UDA© (Yagi) antennas used in the Merwin ATE. Three-element Yagi antennas were oriented in two ways, vertically and horizontally relative to the surface of the river. At the BRG site, four vertically mounted 3-element antennas were combined and amplified to detect tagged fish in the tailrace directly beneath the Merwin access bridge. At the APR site, a single vertically mounted 3-element antenna was pointed at the transition area to accurately detect fish between the adult trap and the tailrace. Three-element antennas at the PWN, PWS, SSS, and NSS sites were mounted horizontally to the tailrace.

Six-element Yagi antennas - Six-element antennas have an intermediate (7 dBd) gain increase, and were used for detecting tagged fish in the mainstem of the Lewis River, specifically at the BLU, BLD, LFH and BBL gate sites. Six-element antennas were successfully used for detecting tagged fish across the entire river channel, thus they were used as gate sites.

Eight-element Yagi antennas – Eight-element antennas have an 11.8 dBd gain increase, the largest increase of the Yagi antennas used in the Merwin ATE. These antennas were used at the NSL and SSL sites, and detected tagged fish within a narrower range than the 3- and 6-element antennas.

Underwater antennas - Underwater antennas were used to detect tagged fish in very small areas where high resolution tracking is needed, such as areas within the Merwin Dam fish passage facilities. While detection probability was important at all sites, for these underwater antennas the explicit array design tradeoff was one that valued specificity (confidence in location) over sensitivity (ability to detect every fish). The typical range of these antennas was 10-20 feet in diameter. Receiver gain settings were typically low for these sites due to the proximity of fish to the receivers in confined areas. Underwater antennas were used exclusively in the adult trap and the collection pool sites. At sites PL2, PL3, and PL4, underwater antennas were contained within ¾ inch electrical conduit tubing attached to the fishway with Hilti® concrete bolts. Underwater antenna cables at the ENT, HOP, and TRP sites were weighted down with lead weights.

The type of aerial antenna used at each site was selected based on the strengths and weaknesses of each antenna type. As discussed above, the 3-element antenna has a shorter but very wide (~80^{o}) tag detection area, while the 8-element antenna has a longer but much narrower (~30^{o}) tag detection area (Figure 23), and the 6-element antenna provides detection areas of intermediate distance and width. Collectively, the use of these three different antennas allowed us to optimize fish detection in different parts of the study area.



3-element antenna

8-element antenna

Figure 23. Reception radiation patterns (tag detection areas) for short-range 3-element (6.0dBd) and long-range 8-element (11.8dBd) Yagi antennas. Numbers around the perimeter of each figure represent directional degrees.

Fish detection ranges varied at receiver sites using the three different antennas depending on mounting orientation and gain settings. Individual antenna orientation and gain settings were optimized for either specificity (trap sites) or sensitivity (most other sites) in detecting tagged fish. Gain settings were adjusted based on empirical results of in-river validation of test radio tags at depths of 5 to 10 feet in the study area.

Two main factors can influence tag detections, tag depth and tag-antenna orientation, with tag depth being the most important factor influencing detections. A radio tag signal loses energy as it travels through water. Radio tags that are deeper in the water column require a longer signal path to reach aerial antennas (and shallow underwater antennas). As a result, the signal from these deeper tags is weaker when it reaches the receiver compared to tags that are shallower in the column. In addition to tag depth, the relative radial/axial orientation between tag and the 6-inch antenna influences signal strength.

Detection ranges were evaluated indirectly during setup optimization and are reported qualitatively, rather than as detection zones with defined areas. After receivers were constructed and antennas were oriented, detection ranges were evaluated for all receivers within the Merwin Dam tailrace. Range testing followed this general protocol:

- A radio tag attached by zip ties and electrical tape to a rope weighted with a cannonball was lowered into the water column from a boat.
- The boat was driven or drifted along a path or paths selected to evaluate detection range for each receiver in the tailrace.

- Receivers were simultaneously monitored for detection of the tag during deployment from the boat.
- Position of the boat and tag was relayed by handheld radio to the person monitoring receivers.
- The tag was drifted at approximately 7 ft. depth for all antenna sites, and at 7 ft. and 25 ft. depth for the Bridge site.
- If detection ranges did not match expectations associated with array design, adjustments were made to receivers.
- Protocol was repeated until detection ranges were as intended (see Figure 5 for intended detection ranges).

Following initial set-up and range testing, routine inspection of detection data was also made throughout the study to verify detection ranges remained as intended.

A-2 Data Management and Processing

Database Construction

Data from weekly 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 one or two 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 GMT time.

Raw detection records were processed and compiled into a single MS Access database. During this process, detections determined to be noise or from a tag code not included in our study were filtered out. 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 stored in separate tables 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, tags from past tracking efforts that remain within the system, 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), with following QA goals:

1) Remove consecutive detections at a single site, with the exception of the first and last detection per visit.
2) Calculate the total number of exit events that an individual made from the trap or from the tailrace regions to categorize fish movements in and around the adult trap and bridge.

To achieve these QA goals, an automated data filter was applied, which 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:
    - A sequence of four detections within 15 minutes of each other was required to be a "credible" detection. If the four consecutive detections spanned more than 15 minutes, it was not considered a credible detection.
    - At the pre-sort pond receiver (Trap), only one 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 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 while these fish were in the tailrace; requiring a strong signal, although conservative from the perspective of sensitivity, provides greater confidence that a fish had passed directly adjacent to the antenna (i.e., this approach optimizes specificity of detections at this site).

- 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.
- Fish were assumed to exit the trap when they moved from any of the trap sites inside the fish ladder (i.e., Entrance, Pool 2, Pool 4, Hopper) to any of the sites outside the trap (i.e., Approach, Bed and Breakfast, Boat Launch sites, Bridge, Lewis River Hatchery, North Shore, Powerhouse North, Powerhouse South, 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.
- Detections at the Bridge site that occur between detections at the pool, hopper, and Trap sites were discarded. These detections were determined to be faulty as there is no way for fish to move between these sites and the bridge in a rapid succession.
- 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.

Database QA Results

There were 1,132,664 detections in the raw data, and 709,344 retained detections after the filter was applied.

Noise detections can prevent an antenna from detecting valid transmissions from a real transmitter (tag). In this study, noise accounted for 385,483 of total detections (34%), a reasonable value considering the conditions of the study (e.g., a dam tailrace and bridge with occasional car and truck traffic). Noise levels were generally higher for receivers located at the trap than those stationed in the tailrace (Figure 24), but the largest "peak" of noise detections came from the tailrace sites. Potential reasons for this pattern include more tagged fish in the system, more tagging events, or operational patterns, noise levels peaked around April 12 (Figure 24). The receivers with the most noise hits were: BLD (48% of all noise detections), ENT (12%), and TRP (10%).

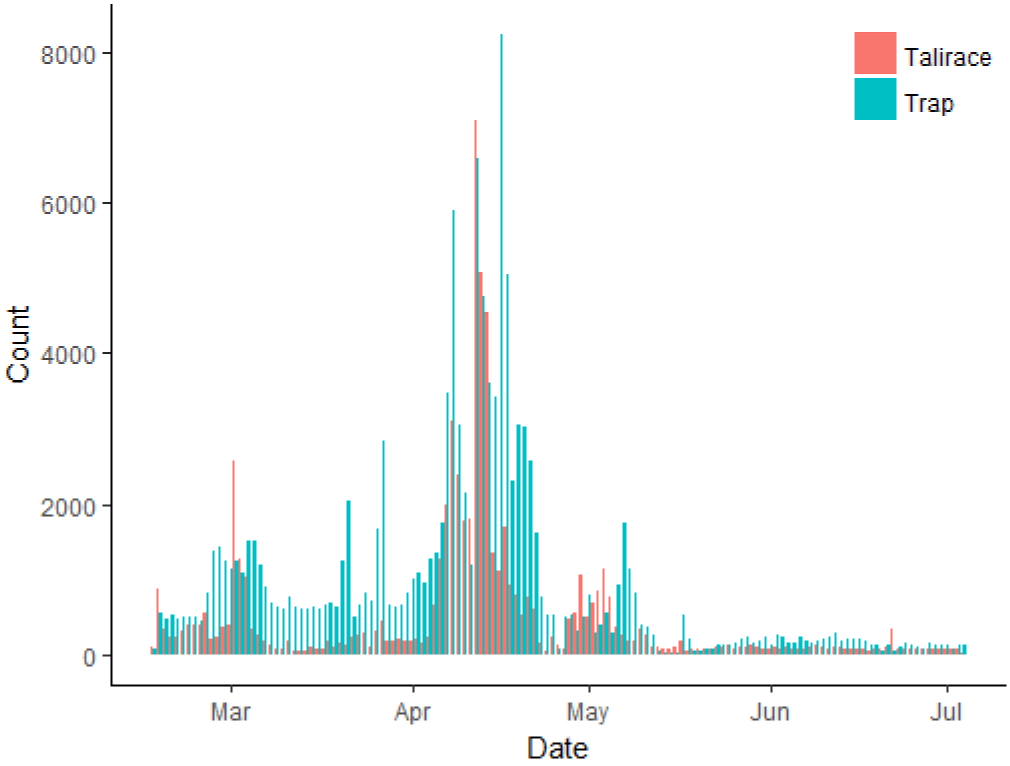


Figure 24. Total number of noise detections for tailrace (red) and trap (blue) receivers.

A-3 Individual Fish Summary Data

Table 10. Individual BWT Winter Steelhead characteristics and detection data summaries from all fish tagged and released in 2018. The ‘Fish Code’ is the unique radio tag code. All radio tags were in the frequency 166.776.

Fish Code	Release Group	Sex	Fork Length (cm)	RAMP Score	Muscle Lipid Content (%)	PIT ID	Release Date/Time	First Detection Location	First Detection Date/Time	Furthest Upstream Detection Location	Furthest Upstream Detection Date/Time	Last Detection Location	Last Detection Date/Time	Recaptured
102	Naïve	F	68	0	0.95	3DD.003C0115B3	3/20/2018 1:11	LRH	4/5/2018 1:08	LRM	4/8/2018 11:50	LRM	5/2/2018 16:22	N
103	Naïve	M	71	0	2.35	3DD.003C01156F	3/2/2018 12:11	LRH	3/10/2018 18:30	TRP	3/28/2018 23:18	TRP	3/28/2018 23:18	Y
104	Naïve	F	66	0	NA	3DD.003C01157D	2/22/2018 2:21	LRH	2/22/2018 14:34	TRP	4/8/2018 18:48	TRP	4/8/2018 18:48	Y
106	Naïve	M	76	0	NA	3DD.003C0115C3	2/22/2018 11:50	LRH	2/24/2018 12:57	TRP	3/23/2018 20:07	TRP	3/23/2018 20:07	Y
107	Naïve	M	62	0	NA	3DD.003C01159F	2/22/2018 11:51	LRH	2/27/2018 8:17	LRH	2/27/2018 8:17	BLD	4/25/2018 7:08	N
110	Naïve	M	63	0	1.25	3DD.003C011598	3/23/2018 11:30	BLD	4/4/2018 15:06	TRP	4/5/2018 18:20	TRP	4/5/2018 18:20	Y
118	Naïve	F	65	0	1.15	3DD.003C0115A7	3/29/2018 11:11	LRH	3/30/2018 19:37	TRP	4/18/2018 16:19	TRP	4/18/2018 16:19	Y
124	Naïve	M	68	0	1.75	3DD.003C0115A4	3/19/2018 11:10	LRH	3/20/2018 13:18	TRP	4/7/2018 2:45	TRP	4/7/2018 2:45	Y
126	Naïve	M	67	0	1.5	3DD.003C01157E	3/12/2018 2:10	BBL	4/4/2018 7:56	TRP	4/6/2018 16:49	TRP	4/6/2018 16:49	Y
127	Naïve	M	65	0	NA	3DD.003C0115A8	3/13/2018 1:25	BLD	3/21/2018 14:07	TRP	3/21/2018 17:39	TRP	3/21/2018 17:39	Y
129	Naïve	F	68	0	1.4	3DD.003C011596	3/19/2018 11:10	LRH	3/25/2018 23:54	TRP	4/10/2018 13:59	TRP	4/10/2018 13:59	Y
130	Naïve	F	77	0	1.65	3DD.003C011574	3/19/2018 11:10	BLD	3/21/2018 17:12	TRP	3/21/2018 21:51	TRP	3/21/2018 21:51	Y
131	Naïve	F	62	0	0.95	3DD.003C0115AF	3/19/2018 12:01	BLD	3/26/2018 18:28	TRP	3/26/2018 22:32	TRP	3/26/2018 22:32	Y
145	Naïve	M	65	0	2.7	3DD.003C0115C2	3/29/2018 1:30	LRH	4/9/2018 18:54	TRP	4/10/2018 16:57	TRP	4/10/2018 16:57	Y
167	Naïve	M	64	0	1.45	3DD.003C0115B4	4/15/2018 11:20	BLD	4/17/2018 7:27	TRP	4/29/2018 12:46	TRP	4/29/2018 12:46	Y
168	Naïve	F	79	0	1.25	3DD.003C0115B2	4/25/2018 10:58	LRH	4/25/2018 14:12	TRP	5/4/2018 14:04	TRP	5/4/2018 14:04	Y
169	Naïve	M	638	0	1.05	3DD.003C0115A5	5/2/2018 11:36	BLD	5/7/2018 8:40	TRP	5/7/2018 12:31	TRP	5/7/2018 12:31	Y
170	Naïve	M	91	0	1	3DD.003C011578	4/19/2018 11:52	BLD	4/30/2018 14:16	LRM	5/11/2018 1:27	LRM	5/11/2018 1:35	N
250	Naïve	F	78	0	1.15	3DD.003C01159A	4/2/2018 11:40	BLD	4/11/2018 16:43	TRP	4/12/2018 15:59	TRP	4/12/2018 15:59	Y
108	Non-Naïve	M	71	0	3.3	3DD.003C010E64	3/20/2018 9:22	LRH	3/20/2018 20:25	TRP	4/17/2018 15:50	TRP	4/17/2018 15:50	Y
109	Non-Naïve	M	79	0	3.7	3DD.003C010E5E	3/20/2018 9:22	LRH	3/23/2018 13:11	LRH	3/23/2018 13:11	LRH	3/23/2018 13:32	N
111	Non-Naïve	F	78	0	1.65	3DD.003C011185	2/22/2018 10:14	BRG	2/22/2018 10:26	TRP	3/9/2018 10:18	TRP	3/9/2018 10:18	Y
112	Non-Naïve	M	62	0	3.2	3DD.003C010E9A	3/20/2018 9:22	BLD	4/10/2018 21:40	TRP	4/13/2018 20:08	TRP	4/13/2018 20:08	Y
113	Non-Naïve	F	68	0	2.45	3DD.003C010E70	3/20/2018 9:22	BLD	4/10/2018 12:26	TRP	4/10/2018 19:46	TRP	4/10/2018 19:46	Y
114	Non-Naïve	M	64	0	2.5	3DD.003C0111AE	2/22/2018 10:14	BLD	2/22/2018 10:20	TRP	4/15/2018 0:53	TRP	4/15/2018 0:53	Y
115	Non-Naïve	M	73	0	1.9	3DD.003C0111C4	2/22/2018 10:14	BLD	2/22/2018 10:20	BLD	2/22/2018 10:20	BLD	2/23/2018 10:44	N
116	Non-Naïve	F	64	0	2.05	3DD.003C0111BC	2/22/2018 10:14	BLD	2/22/2018 10:20	TRP	3/3/2018 13:13	TRP	3/3/2018 13:13	Y
117	Non-Naïve	M	71	0	0.9	3DD.003C0111B9	2/22/2018 10:14	BLD	2/22/2018 11:05	TRP	3/14/2018 8:41	TRP	3/14/2018 8:41	Y
121	Non-Naïve	M	76	0	2.6	3DD.003C010EB9	3/20/2018 9:22	LRH	3/29/2018 12:43	TRP	4/13/2018 19:23	TRP	4/13/2018 19:23	Y
123	Non-Naïve	M	71	0	2.75	3DD.003C010EF9	3/28/2018 9:26	BLU	3/28/2018 9:35	TRP	4/12/2018 15:51	TRP	4/12/2018 15:51	Y
125	Non-Naïve	F	66	0	1.5	3DD.003C010F12	3/29/2018 9:16	BRG	3/29/2018 14:30	TRP	3/30/2018 15:57	TRP	3/30/2018 15:57	Y
128	Non-Naïve	M	67	0	1.25	3DD.003C010EC2	3/28/2018 9:26	BLD	3/28/2018 9:51	HOP	4/14/2018 14:23	BLD	4/19/2018 20:52	N

Fish Code	Release Group	Sex	Fork Length (cm)	RAMP Score	Muscle Lipid Content (%)	PIT ID	Release Date/Time	First Detection Location	First Detection Date/Time	Furthest Upstream Detection Location	Furthest Upstream Detection Date/Time	Last Detection Location	Last Detection Date/Time	Recaptured
132	Non-Naïve	M	62	0	2.1	3DD.003C0111BE	2/28/2018 8:59	BLD	2/28/2018 9:04	TRP	4/2/2018 12:30	TRP	4/2/2018 12:30	Y
133	Non-Naïve	F	66	0	2.3	3DD.003C01119A	2/28/2018 8:59	BLD	2/28/2018 9:04	TRP	3/31/2018 12:50	TRP	3/31/2018 12:50	Y
134	Non-Naïve	M	66	0	2.4	3DD.003C010F17	3/29/2018 9:16	BLD	3/29/2018 9:23	TRP	3/30/2018 14:58	TRP	3/30/2018 14:58	Y
135	Non-Naïve	M	66	0	1.45	3DD.003C01117D	2/28/2018 8:59	BLD	2/28/2018 9:04	TRP	3/29/2018 14:10	TRP	3/29/2018 14:10	Y
136	Non-Naïve	M	63	0	2.15	3DD.003C0111B0	2/28/2018 8:59	BLD	2/28/2018 9:07	TRP	3/6/2018 17:41	TRP	3/6/2018 17:41	Y
137	Non-Naïve	F	62	0	1.9	3DD.003C01117B	2/28/2018 8:59	BLD	2/28/2018 10:09	TRP	3/4/2018 16:08	TRP	3/4/2018 16:08	Y
138	Non-Naïve	F	68	0	1.05	3DD.003C010E9E	3/20/2018 9:22	BLD	3/20/2018 9:27	BBL	3/30/2018 19:06	BBL	4/7/2018 10:50	N
139	Non-Naïve	M	68	0	1.1	3DD.003C010F1A	3/29/2018 9:16	BLD	3/29/2018 9:21	TRP	4/10/2018 22:41	TRP	4/10/2018 22:41	Y
140	Non-Naïve	M	73	0	1.85	3DD.003C0111F8	3/13/2018 11:44	BLD	3/13/2018 11:49	APR	3/21/2018 17:00	BLD	3/23/2018 15:35	N
141	Non-Naïve	F	71	0	2.15	3DD.003C01121C	3/13/2018 11:44	BLU	3/13/2018 12:07	TRP	3/17/2018 4:33	TRP	3/17/2018 4:33	Y
142	Non-Naïve	M	71	0	3.05	3DD.003C0111F2	3/13/2018 11:44	BLD	3/13/2018 13:06	TRP	4/2/2018 13:51	TRP	4/2/2018 13:51	Y
143	Non-Naïve	M	68	0	2.4	3DD.003C0111E0	3/13/2018 11:44	BLD	3/13/2018 11:49	PL2	4/10/2018 17:23	BLD	4/19/2018 10:22	N
144	Non-Naïve	M	68	0	3.1	3DD.003C0111F4	3/13/2018 11:44	BLD	3/13/2018 17:44	TRP	3/25/2018 15:06	TRP	3/25/2018 15:06	Y
146	Non-Naïve	M	72	0	2.05	3DD.003C010E16	3/7/2018 9:11	BLD	3/7/2018 9:17	TRP	4/12/2018 19:37	TRP	4/12/2018 19:37	Y
147	Non-Naïve	M	68	0	3.5	3DD.003C010E01	3/7/2018 9:11	BLD	3/7/2018 10:10	TRP	4/6/2018 9:53	TRP	4/6/2018 9:53	Y
148	Non-Naïve	M	71	0	4.1	3DD.003C010E55	3/7/2018 9:11	BLD	4/4/2018 18:07	TRP	4/5/2018 1:09	TRP	4/5/2018 1:09	Y
149	Non-Naïve	M	69	0	3	3DD.003C010E58	3/7/2018 9:11	BLD	3/7/2018 9:16	TRP	4/13/2018 13:17	TRP	4/13/2018 13:17	Y
150	Non-Naïve	M	74	0	3.4	3DD.003C010E52	3/8/2018 8:41	BLU	3/8/2018 8:49	TRP	3/22/2018 17:42	TRP	3/22/2018 17:42	Y
151	Non-Naïve	F	79	0	1	3DD.003C010EC4	4/3/2018 9:37	BLU	4/3/2018 12:53	TRP	4/4/2018 21:08	TRP	4/4/2018 21:08	Y
152	Non-Naïve	F	69	0	1.05	3DD.003C010EF5	4/3/2018 9:37	BLD	4/3/2018 9:50	TRP	4/14/2018 4:24	TRP	4/14/2018 4:24	Y
153	Non-Naïve	M	72	0	2.65	3DD.003C010F02	4/3/2018 9:37	BLD	4/3/2018 15:47	TRP	4/14/2018 17:33	TRP	4/14/2018 17:33	Y
154	Non-Naïve	M	65	0	2.2	3DD.003C010EC3	4/3/2018 9:37	BLD	4/3/2018 9:42	TRP	4/10/2018 12:59	TRP	4/10/2018 12:59	Y
155	Non-Naïve	F	67	0	1.3	3DD.003C010EEF	4/3/2018 9:37	BLD	4/3/2018 9:52	TRP	4/5/2018 10:04	TRP	4/5/2018 10:04	Y
156	Non-Naïve	M	65	0	3.25	3DD.003C010F19	4/3/2018 9:37	LRH	4/3/2018 17:39	TRP	4/16/2018 23:43	TRP	4/16/2018 23:43	Y
157	Non-Naïve	F	69	0	1.05	3DD.003C010ED6	4/3/2018 9:37	BLD	4/3/2018 9:42	TRP	4/4/2018 22:07	TRP	4/4/2018 22:07	Y
158	Non-Naïve	M	68	0	1.1	3DD.003C011280	4/3/2018 9:37	BLD	4/3/2018 9:42	TRP	4/4/2018 8:41	TRP	4/4/2018 8:41	Y
159	Non-Naïve	M	60	0	1.15	3DD.003C0112A1	4/3/2018 9:37	BLD	4/3/2018 13:13	TRP	4/12/2018 19:37	TRP	4/12/2018 19:37	Y
160	Non-Naïve	F	85	0	1	3DD.003C011285	4/3/2018 9:37	BLD	4/3/2018 11:47	HOP	4/5/2018 13:39	BLD	4/12/2018 17:56	N
161	Non-Naïve	F	80	0	1.15	3DD.003C01125D	4/4/2018 9:25	BLD	4/4/2018 9:39	TRP	4/12/2018 23:39	TRP	4/12/2018 23:39	Y
162	Non-Naïve	F	86	0	2	3DD.003C011287	4/4/2018 9:25	BLD	4/4/2018 13:44	TRP	4/5/2018 16:00	TRP	4/5/2018 16:00	Y
163	Non-Naïve	F	71	0	2.3	3DD.003C01129E	4/4/2018 9:25	BLD	4/4/2018 19:23	TRP	4/6/2018 13:51	TRP	4/6/2018 13:51	Y
164	Non-Naïve	F	77	0	1	3DD.003C011271	4/4/2018 9:25	BLD	4/4/2018 20:09	TRP	4/6/2018 9:51	TRP	4/6/2018 9:51	Y
165	Non-Naïve	M	72	0	2.95	3DD.003C011269	4/4/2018 9:25	BLD	4/4/2018 10:11	TRP	4/11/2018 17:22	TRP	4/11/2018 17:22	Y
166	Non-Naïve	M	69	0	2.4	3DD.003C011263	4/4/2018 9:25	BLD	4/4/2018 10:03	TRP	4/10/2018 13:00	TRP	4/10/2018 13:00	Y
172	Non-Naïve	M	69	0	3.5	3DD.003C01167C	4/11/2018 10:00	BLD	4/11/2018 10:13	HOP	4/19/2018 9:11	SS	4/19/2018 21:09	N
173	Non-Naïve	F	69	0	1.05	3DD.003C011642	4/11/2018 10:00	BLD	4/11/2018 10:11	TRP	4/12/2018 16:07	TRP	4/12/2018 16:07	Y
174	Non-Naïve	F	66	0	1.05	3DD.003C011685	4/11/2018 10:00	BLD	4/11/2018 15:37	TRP	4/17/2018 14:09	TRP	4/17/2018 14:09	Y

Fish Code	Release Group	Sex	Fork Length (cm)	RAMP Score	Muscle Lipid Content (%)	PIT ID	Release Date/Time	First Detection Location	First Detection Date/Time	Furthest Upstream Detection Location	Furthest Upstream Detection Date/Time	Last Detection Location	Last Detection Date/Time	Recaptured
175	Non-Naïve	M	64	0	1.7	3DD.003C011656	4/11/2018 10:00	BLD	4/11/2018 10:15	TRP	4/11/2018 17:41	TRP	4/11/2018 17:41	Y
176	Non-Naïve	F	62	0	1	3DD.003C01164F	4/11/2018 10:00	BLD	4/11/2018 10:05	TRP	4/19/2018 17:11	TRP	4/19/2018 17:11	Y
177	Non-Naïve	M	70	0	1	3DD.003C01168C	4/11/2018 10:00	BLD	4/11/2018 10:15	LRM	5/7/2018 11:13	BBL	6/21/2018 18:19	N
178	Non-Naïve	M	66	0	1	3DD.003C01166C	4/11/2018 10:00	BLD	4/16/2018 12:24	BLD	4/16/2018 12:24	BLD	4/16/2018 12:26	N
179	Non-Naïve	M	66	0	3	3DD.003C011667	4/11/2018 10:00	BLU	4/11/2018 12:30	TRP	4/14/2018 10:22	TRP	4/14/2018 10:22	Y
180	Non-Naïve	F	66	0	1.25	3DD.003C011668	4/11/2018 10:00	BLD	4/11/2018 12:00	TRP	4/17/2018 14:10	TRP	4/17/2018 14:10	Y
181	Non-Naïve	M	68	0	3.15	3DD.003C01167A	4/11/2018 10:00	BLD	4/11/2018 12:25	TRP	4/15/2018 14:11	TRP	4/15/2018 14:11	Y
182	Non-Naïve	M	68	0	1.3	3DD.003C010BC0	4/17/2018 9:23	BRG	4/27/2018 6:00	TRP	5/4/2018 14:00	TRP	5/4/2018 14:00	Y
183	Non-Naïve	M	73	0	3.3	3DD.003C010BBC	4/17/2018 9:23	BLU	4/20/2018 9:08	TRP	5/15/2018 15:56	TRP	5/15/2018 15:56	Y
184	Non-Naïve	M	67	0	2.75	3DD.003C010BC8	4/17/2018 9:23	LRH	4/26/2018 2:41	TRP	5/9/2018 16:37	TRP	5/9/2018 16:37	Y
185	Non-Naïve	F	71	0	2.2	3DD.003C010BCC	4/19/2018 9:48	BLD	4/19/2018 9:56	TRP	4/20/2018 19:00	TRP	4/20/2018 19:00	Y
186	Non-Naïve	F	68	0	1.05	3DD.003C010BFF	4/19/2018 9:48	BLD	4/19/2018 9:54	TRP	4/20/2018 17:00	TRP	4/20/2018 17:00	Y
187	Non-Naïve	M	64	0	2.15	3DD.003C010BE6	4/19/2018 9:48	LRH	4/20/2018 12:48	TRP	5/6/2018 17:39	TRP	5/6/2018 17:39	Y
188	Non-Naïve	F	69	0	1	3DD.003C010BC9	4/19/2018 9:48	BLU	4/19/2018 12:15	TRP	4/20/2018 9:04	TRP	4/20/2018 9:04	Y
189	Non-Naïve	F	69	0	0.95	3DD.003C010BA0	4/19/2018 9:48	BLD	4/19/2018 14:07	LRM	5/4/2018 23:26	LRM	5/4/2018 23:27	N
190	Non-Naïve	F	68	0	1	3DD.003CO10C03	4/24/2018 9:29	BLU	4/24/2018 16:01	TRP	5/4/2018 4:09	TRP	5/4/2018 4:09	Y
191	Non-Naïve	F	69	0	2.25	3DD.003CO10C1C	4/24/2018 9:29	BLD	4/24/2018 10:28	TRP	4/25/2018 14:13	TRP	4/25/2018 14:13	Y
192	Non-Naïve	F	82	0	1	3DD.003CO10C32	4/24/2018 9:29	BLU	4/24/2018 15:40	PL2	4/24/2018 18:14	BLD	4/24/2018 20:21	N
199	Non-Naïve	M	73	0	1.25	3DD.003C010F1C	3/29/2018 9:16	BLD	3/29/2018 9:23	TRP	4/12/2018 13:40	TRP	4/12/2018 13:40	Y
246	Non-Naïve	M	92	0	1.05	3DD.003C010EE5	3/29/2018 9:16	LRH	3/29/2018 20:18	TRP	4/11/2018 9:16	TRP	4/11/2018 9:16	Y
247	Non-Naïve	F	63	0	1.05	3DD.003C010EC0	3/29/2018 9:16	BLD	3/29/2018 9:22	TRP	4/10/2018 15:58	TRP	4/10/2018 15:58	Y
248	Non-Naïve	M	72	0	2.5	3DD.003C010EEA	3/29/2018 9:16	BLD	3/29/2018 12:09	TRP	4/1/2018 8:41	TRP	4/1/2018 8:41	Y
249	Non-Naïve	F	65	0	1.55	3DD.003C010EEB	3/29/2018 9:16	BLD	3/29/2018 10:18	TRP	4/10/2018 14:11	TRP	4/10/2018 14:11	Y
104.1	Non-Naïve$_2$	F	66	0	NA	3DD.003C01157D	4/9/2018 10:04	BLD	4/9/2018 10:09	BLD	4/9/2018 10:09	BLD	4/19/2018 20:49	N
118.1	Non-Naïve$_2$	F	65	0	1.15	3DD.003C0115A7	4/19/2018 9:48	BLD	4/19/2018 10:49	LRM	5/3/2018 3:00	LRM	5/3/2018 3:18	N
124.1	Non-Naïve$_2$	M	68	0	1.75	3DD.003C0115A4	4/7/2018 10:04	BLD	4/9/2018 10:37	TRP	4/14/2018 13:20	TRP	4/14/2018 13:20	Y
126.1	Non-Naïve$_2$	M	67	0	1.5	3DD.003C01157E	4/7/2018 10:04	SS	4/9/2018 14:31	TRP	4/12/2018 14:39	TRP	4/12/2018 14:39	Y
127.1	Non-Naïve$_2$	M	65	0	NA	3DD.003C0115A8	3/22/2018 9:28	LRH	4/10/2018 17:11	TRP	5/2/2018 1:54	TRP	5/2/2018 1:54	Y
130.1	Non-Naïve$_2$	F	77	0	1.65	3DD.003C011574	3/22/2018 9:28	BLD	3/22/2018 9:33	TRP	3/27/2018 21:40	TRP	3/27/2018 21:40	Y
145.1	Non-Naïve$_2$	M	65	0	2.7	3DD.003C0115C2	4/11/2018 10:00	BLD	4/11/2018 10:59	NS	4/26/2018 9:29	LRM	5/30/2018 14:41	N

APPENDIX C

MERWIN ADULT TRAP EFFICIENCY EVALUATION (COHO SALMON) – 2018 REPORT

Responses to Comments Received on 2019 Coho ATE Review

Commenter	Comment Number	Location	Comment	Response
Joshua Ashline, NMFS	1	Page iv bullet number 4	The percentages are incorrect o 16/78 =20.5% 17/78=21.7	These values have been adjusted in the Final Report.
Joshua Ashline, NMFS	2	Page 2	I think it would be helpful with future reports to have a Timeline table describing upgrades to the Merwin Facility by year, and why they were implemented.	This has been noted and PacifiCorp agrees that this would be a good addition to future reports
Joshua Ashline, NMFS	3	Pages 16-17 bulleted lists	Consistency with capitalization at the start of each bullet, the first bulleted list on page 16 is capitalized the second and third are all lower case	Final Report edited for consistency
Joshua Ashline, NMFS	4	Page 19 Table 3	Capitalize total for consistency and aesthetics	Final Report edited for consistency
Joshua Ashline, NMFS	5	Page 21 Figure 6	It would be helpful to have a legend that identifies the site codes, so you don't have to keep flipping back to Table 2 to reference. Alternatively the axis labels could be rotated 90 degrees and spelled out.	Descriptions were added for the site abbreviations in the figure legend.
Joshua Ashline, NMFS	6	Page 27 Figure 8	Same as above	Descriptions were added for the site abbreviations in the figure legend.
Joshua Ashline, NMFS	7	Page 29 Figure 9	Same as above	Descriptions were added for the site abbreviations in the figure legend.
Joshua Ashline, NMFS	8	Page 30 Figure 10	I think this figure would be "cleaner" if presented as two box plots with different axis values next to one another. Also it would be helpful to remove the major outlier from the "fail" plot to capture the quantiles and median values in a box plot.	A second panel was inserted that zooms in on the Naïve fish data to better show the quantiles and median value. Figure axis was changed from mean to median in the plot.
Joshua Ashline, NMFS	9	Pages 32-34 Table 6 and Figures 11,12	Site code identifier as described above	Descriptions were added for the site abbreviations in the figure legend.
Joshua Ashline, NMFS	10	Page 35 Figure 13	See my comment above about figure 10. The Naïve box plot is not informative.	The Naïve boxplot only represents data from a single fish and text was included describing this and cautioning comparisons using this data. Nonetheless, the figure displays the data in an appropriate way and therefore, the only changes made were to insert the median value rather than the mean.
Joshua Ashline, NMFS	11	Page 36 Table 7	Site code identifier	Descriptions were added for the site abbreviations in the figure legend.
Joshua Ashline, NMFS	12	Page 37 Sentence one	Distinction is spelled incorrectly	Spelling error corrected
Joshua Ashline, NMFS	13	Page 37 number 3	Locations is spelled incorrectly	Spelling error corrected
Joshua Ashline, NMFS	14	Page 38 Figure 14	Site code identifier, at this point all figures moving forward should have a site code identifier, for ease of interpretation	Descriptions were added for the site abbreviations in the figure legend.
Joshua Ashline, NMFS	15	Page 43 Figure 18	This box plot identifies the median value the previous say mean, they should all display the median value, as that is what the line within the box plot identifies.	All the boxplots were adjusted so that median value is identified

Commenter	Comment Number	Location	Comment	Response
Joshua Ashline, NMFS	16	Page 46	Fish Energetic State, sentence 1: Add the N value used to calculate the muscle lipid summary statistics o Rest of paragraph: what kind of relationship(s), identify the statistical test i.e linear, GLM, or wilcox rank test. I shouldn't have to go back to the methods to find out.	Sample sizes used to calculate summary statistics for muscle lipid content were added and identified what statistical test was used to examine relationships.
Joshua Ashline, NMFS	17	Page 47 Figure 20	Consider a different shading color for the naïve group, it makes it very difficult to see the median line. Also consider inserting the median values for each box plot.	Shading for the Naïve release group was changed to a lighter shade of grey. The median line is now visible. We did not insert the median values as the medians are clear due to the scale of the boxplot.
Joshua Ashline, NMFS	18	General Comments	Phase 1 trap location and design is referenced several times within the report. The fish passage Phase plan should be attached as an appendix to all the ATE reports.	The Phase plan is a very large document (157 pages) and therefore, PacifiCorp don't think it is a good idea to include as an appendix. Authors did insert additional references for the document when discussing the Phase 1 trap location.
Joshua Ashline, NMFS	19	General Comments	Fish captured at the Merwin facility should be scanned for muscle lipid content as well so an assessment of lipid content loss rate can be explored. This could lay the foundation for assessing if the ladder system is too metabolically expensive for fish to navigate.	PacifiCorp agrees that scanning fish re-captured at the Merwin facility could be informative, and have already incorporated that into the current study on Steelhead ATE.
Joshua Ashline, NMFS	20	On Page 20 bullet 4 the note	This is a metric that needs to be addressed, as entrance detections are used for some ATE calculations, and tailrace residency time. Fish moving quickly though this area could be fixed with faster scanning times for each frequency, or the addition of another receiver cycling frequencies in a different order.	o Reserachers have tried different types of antennas (loop-V and underwater) with similar results, but will look into additional changes that can be made. o We note that we assign fish as having entered the trap if they are detected on the Entrance receiver or any receiver further upstream. Based on the data collected for these sites over a number of years, all fish detected on the Entrance receiver are detected at the Pool 2 receiver. The detections on these two receivers occur very soon (less than a minute) after one another providing evidence that fish that choose to enter the trap pass the Entrance receiver rapidly and there is little delay before being detected on the next upstream receiver, Pool 2. We further note that tailrace residence time includes the time fish spend in the trap before being trapped so that metric is not affected by the low detection efficiency of the Entrance receiver.

Commenter	Comment Number	Location	Comment	Response
Tom Wadsworth WDFW	21	General Comments	Via Email: Dated March 8, 2019: Hi Chris I had a chance to look through this report pretty quickly. Overall I thought it was well done and the results covered the key points. This basically confirms some of our discussions about the need to tag NOR coho for this study as the HORs often go to the hatchery (regardless of naïve or non-naïve). Unfortunately not many NORs were tagged this time but with only half of those (4) reaching the tailrace it suggests that using non-naïve NORs might be the way to go to help avoid tagging fish not destined for the upper river. The coho forecasts for the Columbia are looking pretty good for 2019, including NORs, but we do not have a forecast specific to the Lewis so its hard to say about the NOR returns there. When would you need to know about whether to do an ATE study for coho this year? Thanks Tom	Responce Via Email: Dated March 8, 2019 Hi Tom – Thanks for looking over the report. Yep, not much of a surprise there with using HORs – they do seem to have an affinity for LRH. Unfortunately, we just couldn't get our hands on enough naïve NORs last fall to make much inference regarding their behavior at Merwin Dam and the trap. While the 2019 Columbia forecast for coho is looking favorable, I still think we will be challenged with getting enough upper basin NORs back to the Lewis to make it worth tagging coho again this fall. We only transported about 48,000 coho smolts downstream in 2016 and even fewer in 2017 (~15,000). For now, it seems that program winter steelhead (BWTs) are providing the best information for us regarding the trap and any future adjustments. If something changes and we do decide to tag coho again this year, we would need to have that decision made by the end of June. I will plan to tee-up a discussion regarding ATE coho during the April or May ATS meeting. Thanks again for taking a look and providing feedback. -Chris

MERWIN UPSTREAM PASSAGE ADULT TRAP EFFICIENCY – COHO SALMON

2018 Final Annual Report

Prepared for:

PacifiCorp
825 NE Multnomah St.
Portland, OR 97232

Prepared by:

Matt Drenner, Kai Ross, Lindsey Belcher, Dan Bingham, Elizabeth Schotman, Ryan Flaherty, and Lucius Caldwell

Cramer Fish Sciences; Portland, OR

February 5, 2019

EXECUTIVE SUMMARY

This report describes results from the fourth year of a radio telemetry 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. This report focuses on results evaluating collection efficiency of Coho salmon (a separate report is available for 2018 winter Steelhead; see Drenner et al. 2018c).

The M&E Plan defines a performance standard of 98% collection efficiency, or Adult Trap Efficiency (*ATE)*, for fish that enter the Merwin Dam tailrace. Overall population *ATE* is estimated from a tagged group of study fish, for which ATE_{test} is calculated. Aside from ATE_{test}, two additional core metrics are presented for evaluating Merwin Dam trap effectiveness. Trap entrance efficiency (P_{EE}) quantifies the proportion of fish entering the Merwin Dam tailrace that subsequently entered the trap, regardless of whether they were eventually captured or exited the trap and returned downstream. P_{EE} indicates the ability of study fish to locate and enter the trap from the tailrace. We also report trap ineffectiveness (T_i), which reflects the difference between P_{EE} and ATE_{test}. Evaluation of T_i can reveal an operational or infrastructural weak link in upstream passage at the trapping device—a failure to capture fish once they have entered the trap rather than a failure to attract fish to the trap entrance.

The objectives of the 2018 Merwin *ATE* evaluation were as follows:

1) Determine ATE_{test} for 2018 and compare this value to the performance standard of 98%.
2) Evaluate directional movement of fish in the tailrace, and trap, and at downstream locations.
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., energetic state, stress levels and injury rates) and how it relates to fish behavior.

To evaluate core passage metrics and behaviors, study years prior to 2018 used fish collected from the Merwin Dam fish trap that were tagged with radio tags and released immediately downstream of Merwin Dam. Thus, all fish had been previously trapped (i.e., they were Non-Naïve to the trap) and core passage metrics were estimated from fish making second attempts to locate and enter the trap. It was proposed that estimates of core passage metrics could be biased if fish were less likely (or less able) to locate and enter the Merwin Dam fish trap a second time.

In 2018, to evaluate the effects of prior encounter with the fish trap on subsequent re-capture rates of fish at the fish trap, core passage metrics and movements were evaluated for two release groups of fish:

- Fish captured and tagged at the Merwin Fish Collection Facility, then subsequently released downstream (i.e., trap Non-Naïve fish);
- Fish captured, tagged and released downstream from Merwin Dam, and thus presumably with no prior encounter with the trap (i.e., trap Naïve fish).

After release, radio telemetry was used to assess collection efficiency and infer movements of tagged fish at locations within Merwin Dam tailrace, Merwin Dam fish trap ladder, and at sites downstream of Merwin Dam in the Lewis River and two of its tributaries.

Core passage metrics from 2015-18 are summarized in Table 1, below. Notably, estimates of ATE_{test} and P_{EE} for Coho salmon in 2018 were the highest across the three years Coho salmon have been evaluated.

Table 1. Values for P_{EE}, ATE_{test}, and T_i across study years. Sample sizes (N) reflect the total number of fish tagged each year. In 2018, Bayesian Highest Density Intervals (HDI) were used to estimate 95% confidence intervals (95% CI) whereas bias-corrected and accelerated bootstrapping methods were used in all other study years. Output from these approaches is comparable, given that HDI were calculated using flat priors.

Study Year	***Species/release group***	***N***	**P_{EE} *(95% CI)***	**ATE_{test} *(95% CI)***	**T_i**
2015	Winter Steelhead	148	86% (79-90%)	61% (51-67%)	29%
	Spring Chinook	40	90%	38%	58%
	Coho Salmon	35	23% (12-40%)	9% (4-28%)	61%
2016	Winter Steelhead	148	93% (87-96%)	73% (65-80%)	21%
2017	Winter Steelhead	150	84% (77-90%)	76% (70-84%)	9%
	Coho Salmon	149	70% (60-83%)	63% (50-74%)	10%
2018	Winter Steelhead	92	99% (94-100%)	93% (85-97%)	6%
	Non-Naïve	*73*	*99% (92-100%)*	*91% (83-96%)*	*8%*
	Naïve	*19*	*100% (80-100%)*	*100% (84–100%)*	*0%*
	Coho Salmon	78	73% (61-91%)	68% (48-83%)	15%
	Non-Naïve	*63*	*75% (63-92%)*	*70% (49-84%)*	*16%*
	Naive	*15*	*50% (N/A)*	*50% (N/A)*	*0%*

Key results from the 2018 study pertaining to the core passage metrics for Coho salmon include the following:

- A total of 78 Coho salmon (combined Non-Naïve and Naïve) were tagged between 21 September – 29 October.
- 77 Coho salmon were detected in the study array in the North Fork Lewis River.
- 25 Coho salmon subsequently entered the tailrace of Merwin Dam following release (composing the group of fish that were included in estimates of core metrics)
- 20 Coho salmon entered the trap, for an overall P_{EE} of 73% (20/25)
    - P_{EE} in 2018 (73%) was three percentage points greater (a 4% increase) than the next highest P_{EE} across all study years for Coho salmon (P_{EE} for Coho salmon in 2017 was 70%)
- 17 Coho salmon were successfully recaptured, for a combined ATE_{test} of 68% (17/25)
    - ATE_{test} in 2018 (68%) is five percentage points greater (an 8% increase) than the next highest ATE_{test} across all study years (ATE_{test} for Coho salmon in 2017 was 63%).
    - 95% confidence intervals for ATE_{test} in 2018 spanned 48-83%, which is below the 98% *ATE* performance standard.
- Comparisons of ATE_{test} to the 98% performance standard indicated there was less than a 0.0001% probability that the true *ATE* of the combined parent population met or exceeded the target.
    - Note: there was no statistical analysis using Naïve Coho salmon alone in 2018 due to low samples sizes of Naïve Coho salmon that entered the tailrace (n=2).

We also compared the amount of time that fish were present in the tailrace to performance standards. Median tailrace residence time was 3.5 hours, which is below the maximum (i.e., achieves) the performance standard of median tailrace residence time less than 24 hours. However, 6% of fish exhibited tailrace residence times greater than 168 hours, which marginally exceeds the maximum (i.e., does not achieve) the performance standard of less than 5% of fish residing within the tailrace for this long. Thus, performance standards for median tailrace time of less than or equal to 24 hours with less than 5% of fish taking longer than 168 hours to pass were partially met for Coho salmon in 2018.

Consistent with previous years, during the 2018 study year, all tagged Coho salmon appeared to locate and enter the trap at a higher rate (P_{EE} of 73%) than the rate at which they were captured (i.e., ATE_{test} of 68%). This observation is reflected by a trap ineffectiveness (T_i) of 15% for 2018, which is greater than T_i in 2017 (10%). T_i in 2017-18 was lower than in 2015 (61%), which is likely a result of the addition of a fyke to the trap prior to 2017 studies. Given that the fyke was in place during the study periods for both 2017 and 2018, we hypothesize that higher T_i (i.e., more trap exits) in 2018 compared to 2017 could be associated with Lewis River discharge. When Lewis River discharge is low, higher flows through the trap ladder may provide fish with a directional cue to locate and exit the trap through the fyke. This hypothesis is consistent with observations between Lewis River discharge and trap retention for winter Steelhead in 2017 and 2018.

Similar to differences in trap retention, differences in *ATE* among study years is likely related to variety of factors including installation of the fyke prior to 2017 and environmental factors such as Lewis River discharge. During Coho salmon tracking in 2018, Lewis River discharge was the lowest and *ATE* was the highest among the three study years for Coho salmon. In contrast, in 2015, Lewis River discharge was the highest and *ATE* was the lowest among study years. Although purely observational, a similar trend was observed for winter Steelhead. Further statistical modeling would be required to understand the influence of Lewis River discharge on passage metrics at Merwin Dam.

Consistent across all study years, Coho salmon appear to have low attraction to the Merwin Dam tailrace and fish trap. Evidence in support low attraction to the trap from 2018 includes:

- After entering the tailrace, Coho salmon showed no preference for the side of the tailrace where attraction flows are emitted from the trap entrance (i.e., the south side).
- Coho salmon milled along both the south and north side of the tailrace.

Evidence in support of low attraction to the Merwin Dam tailrace from 2018 includes:

- Few Coho salmon released reached the tailrace (only 32% entered the tailrace).
- Approximately the same number of Coho salmon that were tagged and released as part of this study were captured at the Lewis River Hatchery (16/78 or 21%) as were captured at the Merwin Dam fish trap (17/78 or 21%) despite a greater number of fish (n=63) being released at an upstream location that was closer to Merwin Dam.
- The site where the most Coho salmon were detected was the Lewis River Hatchery (58 fish detected at this site or 74% of total released)
- Coho salmon spent the most time (>50% of total time) at the Lewis River Hatchery site.
- Nine Coho salmon were detected in two tributaries of the NF Lewis River, Cedar Creek and the East Fork Lewis River. Taken together, these observations suggest straying behaviors. Five of these nine fish were last detected in these tributaries indicating they may have been strays or originated from these tributaries.
- Five fish were detected at the Lewis River Mouth site, two of which were last detected at this site and therefore may have exited the system.

Indeed, it appeared that Coho salmon were generally not attracted to Merwin Dam. In contrast, Coho salmon may have been more attracted to the Lewis River Hatchery. The majority (70/78 or 90%) of fish in this study were hatchery origin (HOR) Coho salmon, which originate from the Lewis River Hatchery. HOR Coho salmon would be expected to return to the hatchery in high proportions and not to be attracted to flows discharged from the Merwin Dam fish trap. Thus, our results that Coho salmon showed a preference for the Lewis River Hatchery over Merwin Dam is perhaps not surprising. Note, that the original intent was to tag more NOR fish (see PacifiCorp 2018), but low numbers of NOR fish resulted in tagging HOR fish as surrogates.

We conclude that the use of HOR Coho salmon for evaluating passage at the Merwin Dam fish trap is potentially inappropriate. Hatchery reared winter Steelhead used for reintroduction (blank wire tagged - BWT), which originate from Merwin Hatchery and show more attraction to Merwin Dam compared to Coho salmon (Drenner et al. 2018c), are likely a better study group for evaluating fish passage at Merwin Dam. Natural origin (NOR) Coho salmon from the upper basin may be another alternative.

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INTRODUCTION

Study Area

The Lewis River is a major tributary of the Columbia River, approximately 140 river km (RKM) (87 river miles, RM) upstream from the Pacific Ocean. The North Fork (NF) Lewis River hydroelectric project begins at Merwin Dam, located at RKM 31.4 (RM 19.5) of the NF Lewis River[1], and extends upstream through two other impoundments. This study is focused on the reach between Merwin Dam and the confluence of the Lewis and Columbia Rivers, near Woodland, Washington (Figure 1). Our analyses for quantifying estimates of core passage metrics focus on fish that were detected within the Merwin Dam tailrace, defined as the area upstream of Merwin Bridge approximately 0.1 km downstream of Merwin Dam (Figure 1). Fish passage at Merwin Dam is facilitated via a fish trap located at the base of Merwin Dam on the South side (Figure 1).

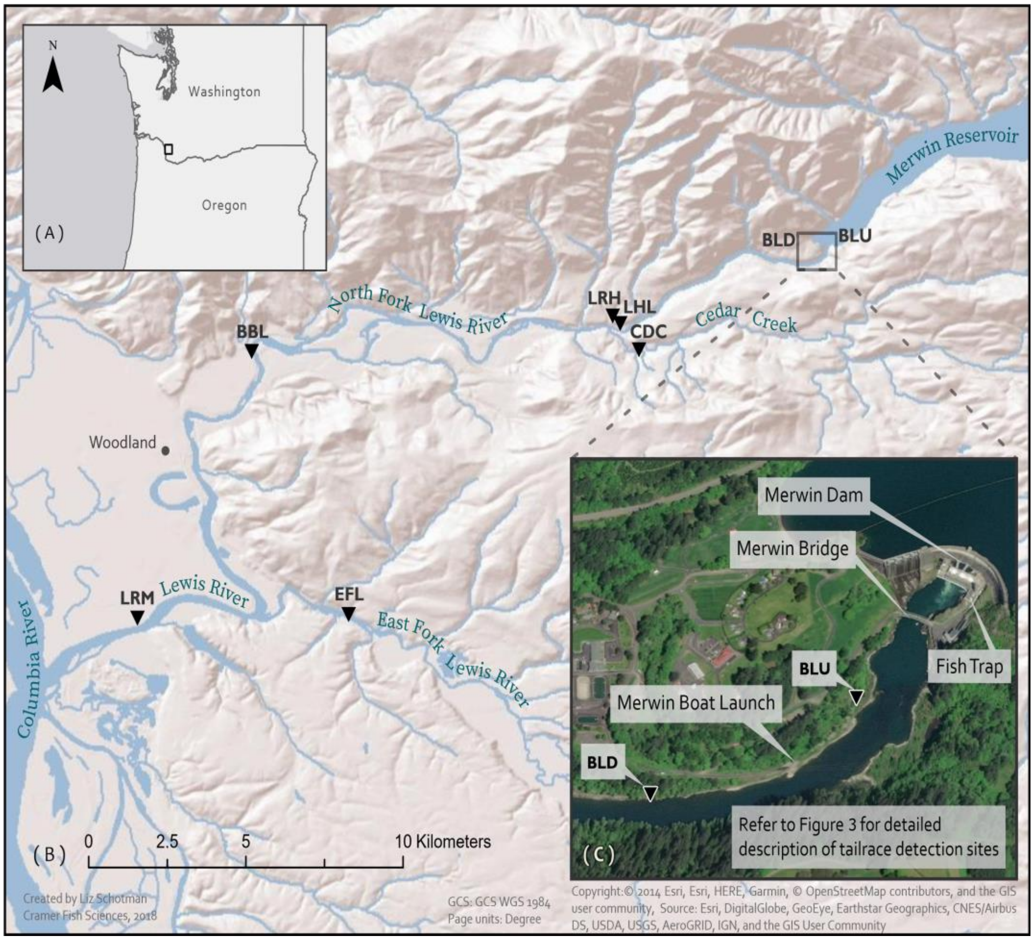

Figure 1. Project area map indicating study region (A), extent of study within the Lewis River system (B), and study area and infrastructure near Merwin Dam (C). Black triangles indicate radio detection sites.

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[1] Throughout the remainder of this document, all river distances refer to Lewis River, i.e., distance upstream from Lewis River confluence with Columbia River

Study Background

The NF Lewis River Hydroelectric Project operates Merwin Dam under a Federal Energy Regulatory Commission license issued to PacifiCorp in June 2008. The license agreement stipulates requirements for reintroduction of salmonids and to provide both upstream and downstream passage of target salmonids (*Oncorhynchus* spp.) including spring Chinook Salmon (*O. tshawytscha*), Coho Salmon (*O. kisutch*), and winter Steelhead *(O. mykiss*) [*for additional details about the licensing agreements see (PacifiCorp and Cowlitz PUD 2016)*].

Among objectives outlined in Phase 1 of the licensing agreement is the need to assess the effectiveness of passage facilities including evaluating adult trap efficiency (*ATE*) of the Merwin Fish Collection Facility (PacifiCorp and Cowlitz PUD 2016). During the licensing process, it was agreed that *ATE* at Merwin Dam should meet or exceed a performance standard of 98% *ATE*. The use of radio telemetry was proposed to evaluate *ATE* because of the ability to actively monitor fish behavior in the tailrace of Merwin Dam.

Following updates to the Merwin Fish Collection Facility in 2014 and beginning in 2015, four years of radio telemetry studies have evaluated *ATE* and other biological metrics of adult salmonids at Merwin Dam and downstream in the NF Lewis River. Results from the first three study years indicated the performance standard of 98% *ATE* was not being achieved (for additional details see Stevens et al. 2016, Caldwell et al. 2017, Drenner et al. 2018a, 2018b). Consequently, over the course of the study years, dam infrastructural and trap and dam operational adaptations have been undertaken to improve *ATE*, which has also resulted in improved understanding of the biological, operational, and environmental factors influencing *ATE*. For example, based on results from 2015 and 2016 study years, which showed relatively high rates of tagged fish entering the trap but lower rates of fish being successfully captured (Stevens et al. 2016 & Caldwell et al. 2017), a single V-style fyke was installed in the trap prior to 2017 studies to prevent fish from returning to the tailrace once they had entered the trap. Results from 2017 showed the fyke was effective in reducing the number of exit events from the trap but estimated *ATE* remained below the 98% performance standard (Drenner et al. 2018a, 2018b).

It was hypothesized that operational and environmental factors, such as flow through the power generating turbines and total background NF Lewis River flow, may influence *ATE* at Merwin Dam. Exploratory comparisons of environmental and operational data between three study years provided weak evidence suggesting winter Steelhead exhibited lower numbers of trap entrance attempts from the Merwin Dam tailrace during higher (> 8,000 cfs) total NF Lewis River discharge (Drenner et al. 2018a). An additional year of data in 2018 provided further evidence that discharge could be influencing *ATE* at Merwin Dam (Drenner et al. 2018c); however, additional analysis is needed to formally evaluate these observations.

Other biological factors were also identified that could contribute to below 98% passage efficiency at Merwin Dam, including fish straying into Lewis River tributaries (i.e., fish entering and potentially spawning in non-natal habitats) and the underlying biological condition of fish used to evaluate *ATE*. To address the former, in 2018, receivers were installed in two tributaries of the Lewis River, which were suspected of attracting strays, and at the confluence of the Lewis and Columbia rivers. Results showed no Steelhead strayed into either of the tributaries in 2018 suggesting low stray rates of blank wire tagged (BWT) winter Steelhead.

To evaluate the influence of fish biological condition on *ATE*, in 2018, fish muscle lipid content, which is a proxy for overall fish condition, was estimated for individual winter Steelhead prior to release. Results from these data indicated winter Steelhead with higher muscle lipid content were more likely to be re-captured compared to fish with lower muscle lipid content. Overall these results indicate the background biological condition of fish that arrive in the Lewis River influence their probability of re-capture at the Merwin Fish Collection Facility.

Consistent among the first three study years, all fish included in *ATE* estimation analyses were first captured at the Merwin Fish Collection Facility, tagged and then released downstream of Merwin Dam (i.e., these fish must locate and enter the trap a second time). The use of previously trapped fish (or fish that successfully ascended a dam fishway) is common in fish passage studies because (1) it increases the likelihood that fish are volitionally targeting upstream spawning habitat, and (2) it is logistically easier to capture fish that are confined in a trap or narrow fishway than fish that are swimming freely in a large river. However, one explicit assumption of CFS's previous Merwin *ATE* studies has been that recapture rates of previously trapped fish accurately and appropriately reflect and equal rates of initial capture among the parent population of fish that never encountered a trap. Few studies have examined the effects of previous experience encountering a fish trap (or fishway) on subsequent passage rates, but in one study, Burnett et al. (2014) showed 16% lower passage rates of Sockeye salmon captured from the top of a dam fishway compared to fish captured from below the dam.

To test the hypothesis that prior encounter with the fish trap influences subsequent re-capture probability, comparisons were made for winter Steelhead in 2018 between groups of fish that were trap Naïve (no previous encounters with trap) and trap Non-Naïve (previously were captured in the trap) (Drenner et al. 2018c). Raw *ATE* values for Naïve fish were 100%, which was above the performance standard of 98% *ATE*, compared to only 91% for Non-Naïve fish. Although *ATE* values were not statistically different between Naïve and Non-Naïve fish, which could be related to low sample sizes of Naïve fish, the results indicated there was an 80% probability that Naïve fish had higher *ATE* compared to Non-Naïve fish. Furthermore, behavioral differences were detected between groups of fish, with Naïve fish spending less time in the tailrace, visiting fewer sites, and having more direct movements compared to Non-Naïve fish. These results provide evidence for biological and potentially meaningful differences between trap Naïve and trap Non-Naïve fish, but additional years of data collection was recommended to further evaluate differences.

Study Objectives

The primary goal of this fourth study year was to continue to evaluate the performance of the Merwin Dam trap location, design, and adequacy of attraction flow using radio telemetry. This study also investigated whether passage metrics and behaviors differed between test fish that were captured and tagged downstream of the trap (i.e., trap Naïve fish) and those that were collected after passing through the trap once, tagged and released back downstream (i.e., trap Non-Naïve fish). This report focuses solely on results from evaluation of adult Coho salmon passage performance and behavior. A separate report for adult winter Steelhead in spring 2018 was presented in a stand-alone report (see Drenner et al. 2018c).

The specific objectives for the 2018 Coho salmon evaluation included the following:

1) Determine *ATE* for Coho salmon at Merwin Dam and compare estimates to the performance standard of 98%.
2) Determine if Coho salmon show directed movement toward the trap entrance; if some fish do not, document the behavior patterns for those fish in the tailrace.
3) Determine if Coho salmon 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 Coho salmon 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 Coho salmon that do not enter or which choose to leave the Merwin Dam tailrace and move back downstream.
6) Determine the condition of Coho salmon that are captured by the trap, as a function of individual fish energetic state, and rates of descaling, injury, and reflex impairment.

Results are presented for, and comparisons made between, trap Naïve and trap Non-Naïve fish within each of the above objectives, when appropriate.

METHODS

Fish Collecting and Tagging

All fish included in this study were either hatchery origin (HOR) or natural origin (NOR) adult Coho salmon collected and tagged by PacifiCorp staff from late-September through late-October 2018. HOR Coho salmon originate from the Lewis River Hatchery located ~ 6 km downstream for Merwin Dam, whereas NOR Coho salmon can originate from different locations including above Merwin Dam, downstream of Merwin Dam, in tributaries of the NF Lewis River or from separate watersheds (for more information on origin of HOR and NOR Coho salmon see PacifiCorp 2014). Estimates of core passage metrics and behaviors were made for the following two release groups of tagged Coho salmon:

- Trap **Non-Naïve** release group – fish were captured and tagged at the Merwin Dam Adult Fish Collection Facility before being transported and released into the NF Lewis River ~ 0.6 km (0.4 mi) downstream of Merwin Dam at the Merwin Boat Launch (Figure 1). This release group is analogous to fish used to estimate core metrics in previous study years, and thus allows interannual comparisons of core metrics across the study years.
- Trap **Naïve** release group – fish were captured by tangle netting and angling, tagged and released in the NF Lewis River. An assumption is that none of the fish included in this release group previously encountered the trap at Merwin Dam. Trap Naïve fish were included to compare core passage metrics of fish that were previously captured (i.e., trap Non-Naïve fish) with fish that had not been previously captured (i.e., trap Naïve fish).

Following capture and prior to release, all fish underwent the same tagging procedure. Briefly, individual fish were transferred into a sampling trough, fork length was measured to the nearest centimeter, a visual assessment of injury was made, a passive integrated transponder (PIT; Full Duplex, 12.5mm, 134.2 kHz) was injected into the dorsal sinus, and a radio transmitter (Lotek MCFT-3a; 166.776 MHz; 16 mm in diameter and 46 mm in length and had a mass of 16 g, giving them a weight of 157 millinewtons in air but only 66 millinewtons in water) was applied by gastric insertion (Figure 2). Latex tubing was used to reduce tag regurgitation for the gastric implants. Radio transmitters were programmed with a burst rate of 5 s, staggered by 0.5 s intervals within release groups (i.e., each group contained fish implanted with tags bursting at 4.5 s, 5 s, and 5.5 s intervals).

To further explore the mechanisms underlying fish passage behavior after release and to account for potential physiological effects of different capture methods (i.e., tangle netting versus fish trapping at the dam), individual fish condition was quantitively assessed prior to release using two methods. First, Reflex Actions Mortality Predictors (RAMP; indicators of acute stress from capture and handling procedures) were assessed for each fish following protocols outlined in Raby et al. (2012). Briefly, five reflexes were assessed categorically (0 = unimpaired, 1 = impaired), and an index was then calculated for each fish based on the proportion of reflexes that were impaired. Additionally, to understand how energetic reserves could influence fish behavior after release, muscle lipid content (a primary depot of energy reserves in salmonids) was estimated for each fish, using handheld microwave radio emitters (Distell Fatmeters, https://www.distell.com/), following protocols presented in Caldwell et al. (2013) (Figure 2).

All fish were allowed to recover following the tagging procedure. Fish tagged at the tangle netting or angling sites downstream (i.e., Naïve fish) were released immediately overboard following the tagging procedure near the location they were captured. Fish tagged at the Merwin Fish Collection Facility (i.e., Non-Naïve and Non-Naive$_2$ fish) were transferred to a water tank on the back of a truck and transported to the release site at the Merwin Boat Launch. A maximum of 10 fish were tagged and released on any given day to reduce the frequency of tag collision.

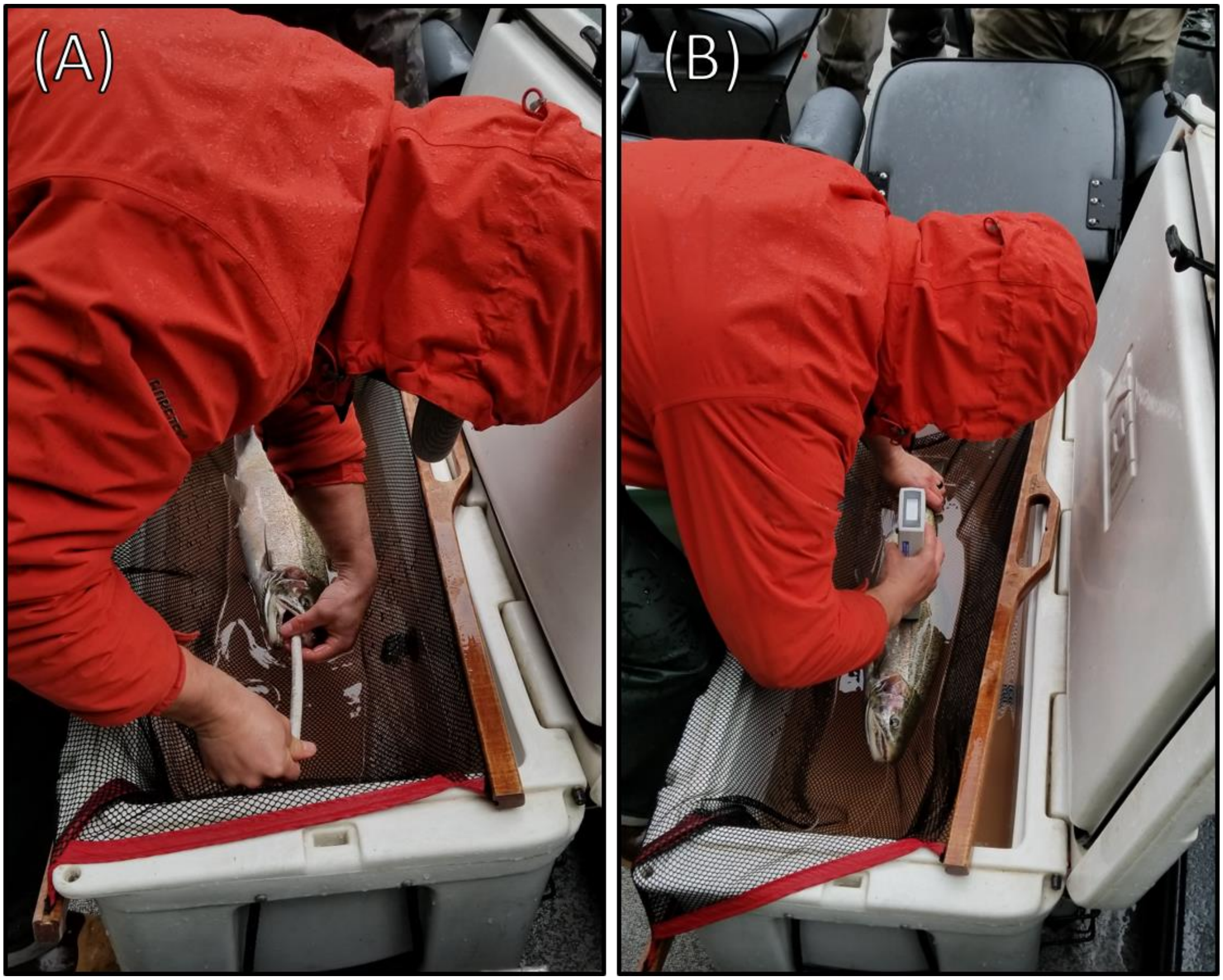

Figure 2. Photos taken during winter Steelhead tagging procedure at the tangle netting site (Drenner et al. 2018c), similar to Coho salmon methods described here. Photos show radio tag being inserted gastrically (A) and Fatmeter being used to measure muscle lipid content (B). Photos courtesy of PacifiCorp.

Fish Tracking

Following release, movements of tagged fish were monitored using fixed radio telemetry stations consisting of 19 detection sites strategically positioned within three distinct study areas (see Table 2, Figure 1, Figure 3, and Figure 4 for individual site descriptions and locations):

- Downstream of Merwin Dam
    - Eight detection sites extending from the confluence of the Lewis River and Columbia River to the Boat Launch downstream of Merwin Dam (Table 2, Figure 1).
- Merwin Dam tailrace
    - Six detection sites within the tailrace with entrance and exit sites at the Bridge and immediately outside the trap entrance (Table 2; Figure 3).
- Merwin Dam trap
    - Five detection sites starting at the entrance to the trap ladder system extending to the trap holding area(Table 2; Figure 4).

Each detection site was deployed in combinations with receivers (19 SRX800D). Receivers had the ability to store approximately 1 million detection records each.

Detection site locations for Coho salmon in 2018 were identical to those used for winter Steelhead in 2018 (Drenner et al. 2018c) with the following exception:

- Lewis Hatchery Ladder (LHL) site was added to study on October 29th, 2018 – located in the ladder leading into the Lewis River Hatchery ~ 6 km downstream of the Merwin Dam tailrace. This antenna site was used to assess numbers of fish attempting to return to the Lewis River Hatchery.

Table 2. Antenna locations, abbreviations, descriptions and purpose for all 19 radio receiver sites used in the study. River kilometers (RKM) are presented as kilometers from the Pacific Ocean.

Study area	Site code	Site name	Antenna description/location	Purpose of site	RKM
Trap	TRP	Collection Pool	Underwater antenna[2] located a few feet from the hopper transfer pipe outflow	Detects fish first entering the collection pool	171.3
"	HOP	Hopper	Two combined underwater dipole antennas located on the east and west sides of the collection hopper	Detects fish inside the fish hopper and the last few feet of the crowder section	171.3
"	PL4	Pool 4	Underwater dipole antenna located at the entrance of Pool 4 downstream from the fish crowder	Detects fish before crowder below the collection hopper	171.3
"	PL2	Pool 2	Underwater dipole antenna located 2 feet from the Pool 2 entrance on the northwest wall of Pool 2	Assesses fish passage and residence time near the Fyke weir	171.3
"	ENT	Entrance	Underwater loop-V antenna at downstream end (entrance) of Trap.	Determines when fish are inside the Trap	171.3
Tailrace	APR	Approach	3 element antenna pointed vertically at Trap entrance	Monitors fish as they approach the Merwin Trap	171.3
"	NS	North Shore	Two radio antennas, one long range 8-element antenna and one short range 3 element antenna, combined into one site	Monitors the North shore of the tailrace	171.3
"	SS	South Shore	Two radio antennas, one long range 8-element antenna and one short range 3-element antenna, combined into one site	Monitors the south shore of the tailrace to the APR site	171.2
"	PWN	Powerhouse North	3 element antenna pointed north parallel to the front of the tailrace deck	Monitors fish in front of the northern half of the Powerhouse	171.3
"	PWS	Powerhouse South	3-element antenna pointed south along the front of the tailrace deck	Monitors fish in front of the southern half of the Powerhouse	171.3
"	BRG	Bridge	Four 3-element antennas located equidistantly along the downstream section of the bridge. The north 2 antennas were amplified producing a uniform detection zone.	Indicates when upstream adult Steelhead first enter the tailrace and are attempting to migrate above Merwin Dam.	171.1
Down-stream	BLU	Boat Launch Upstream	6-element antenna downstream of the BRG site	Determines direction of fish migration relative to the fish release site at the Merwin Dam Boat Launch	170.8
"	BLD	Boat Launch Downstream	6-element antenna downstream of the release site	Determines direction of fish migration relative to the fish release site at the Merwin Dam Boat Launch	170.3
"	CDC	Cedar Creek	6-element antenna in Cedar Creek	Monitor fish entering Cedar Creek	166.3

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[2] Underwater loop-V antenna was used until approximately April 1st, after which an underwater dipole antenna was used at this location.

Study area	Site code	Site name	Antenna description/location	Purpose of site	RKM
	LHL	Lewis Hatchery Ladder	Underwater dipole antenna located within the ladder system leading into the Lewis River Hatchery	Monitor fish entering Lewis River Hatchery	165.4
"	LRH	Lewis River Hatchery	6-element antenna at the NF Lewis River/Cedar Creek confluence	Determines direction of fish migration relative to the Merwin Dam release site	165.2
"	BBL	Bed Breakfast Lewis River	6-element antenna on the NF Lewis River in Woodland, Washington	Confirms fish in study area	152.0
"	EFL	East Fork Lewis River	6-element antenna on the East Fork Lewis River	Monitor fish entering the East Fork Lewis River	148.7
"	LRM	Lewis River Mouth	6-element antenna on the Lewis River near it’s confluence with the Columbia River	Confirm fish in the study area and potential of fish exiting the Lewis River	142.5

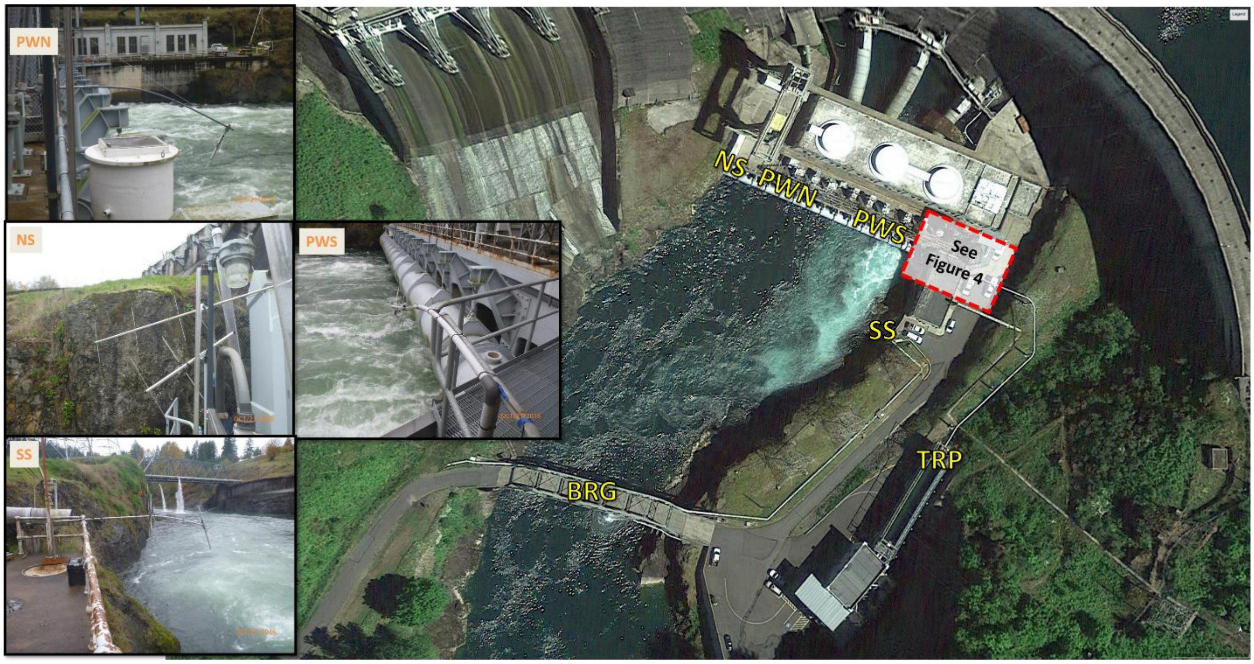

Figure 3. Merwin Dam tailrace area with locations of stationed antennas and pictures of select antenna orientations. All antennas listed in this figure are aerial, except for the Trap. Details of antennas deployed within the trap are shown on the trap schematic in Figure 4. Aerial image taken from Google Earth. All other photos provided by Cramer Fish Sciences.

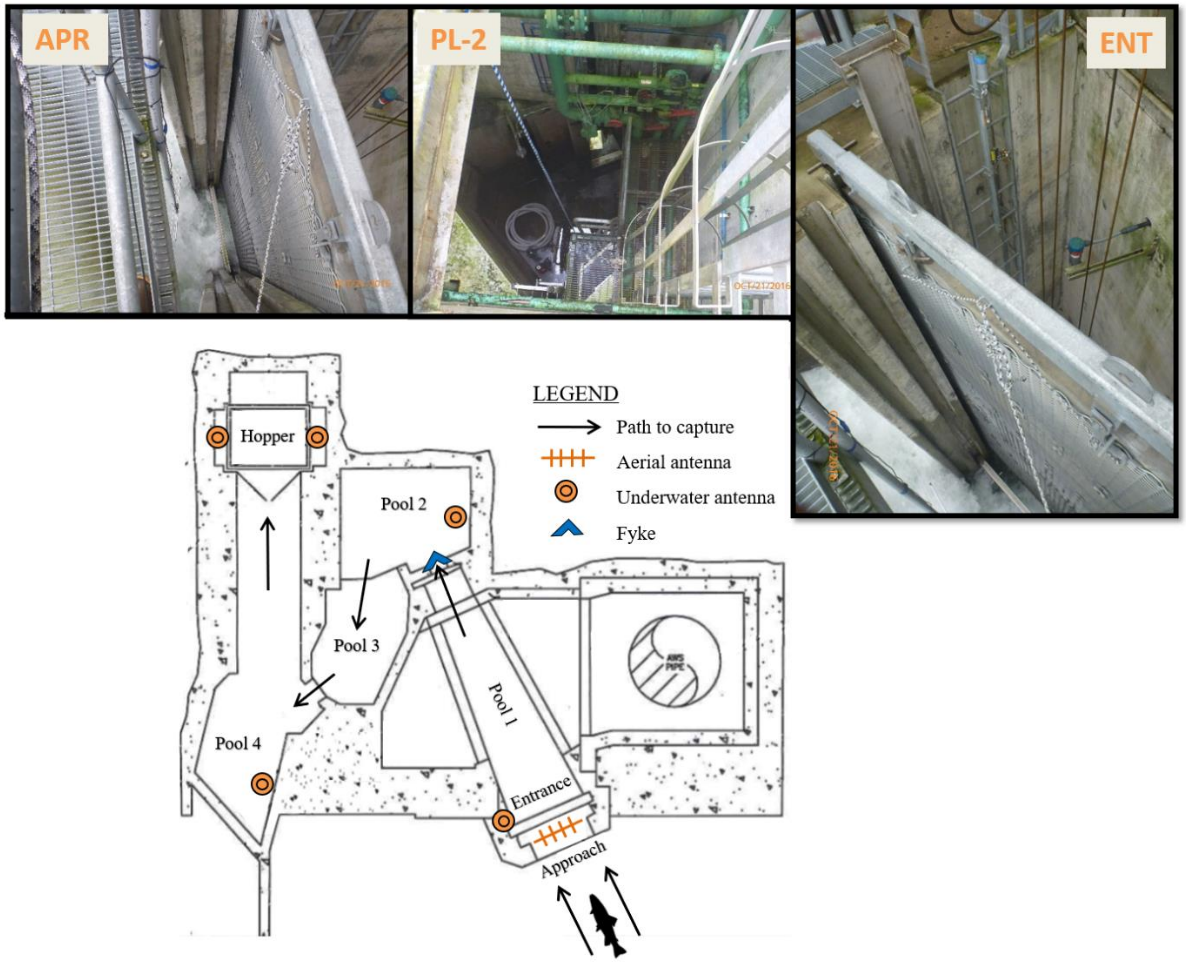

Figure 4. Trap schematic showing the locations of antenna arrays, with arrows showing the progressive movements fish make to reach the hopper and pictures of select antenna orientations. Photos provided by Cramer Fish Sciences.

Detection capabilities

Tag detection ranges for each radio receiver were designed to meet specific goals related to each detection site and study area. For example, radio detection sites downstream of the tailrace were designed to act as ‘gates’ that detect fish passing the site in either direction across the entire river channel. Similarly, the Bridge site acts as the ‘start gate’ for fish entering the tailrace. Detection regions within the tailrace were designed to create overlapping regions that identify specific fish movements within the tailrace (see generalized tailrace detection regions presented in Figure 5). Detection regions within the trap were designed to detect fish within the respective trap location.

Detection ranges were evaluated manually for all receivers in the tailrace (see Appendix A-1 for additional details on range testing protocols). Following initial set-up and range testing, routine inspections of detection data were also made throughout the study to verify detection ranges remained as intended. Beacon tags (i.e., radio tags that are programmed to emit signals once every hour) were deployed at a fixed location near each detection site, except Pool 4, to confirm all antennas continued to function properly over the study duration.

Figure 5. Locations of intended detection regions for six radio receivers located from the bridge upstream and into the fish passage facilities at Merwin Dam.

Data Management and Processing

Receiver sites were inspected and downloaded either weekly or bi-weekly throughout the study. Raw detection data were filtered to remove noise and tag codes not included in the study, and filtered data were compiled into a secure and backed-up relational database (for additional details see Appendix A-2). A second filtering process developed by Stevens et al. (2015) was applied the data. This filtering process is described in previous reports (e.g., see Drenner et al. 2018b) and presented in Appendix A-2, in addition to results pertaining data management and processing.

Following data filtration, all individual fish detection histories were visually inspected.

Analytical Approach

Objective 1: Determine trap effectiveness based on ATE and other core metrics (a), compare estimates to the ATE performance standard of 98% (b), and test for temporal trend in ATE (c)

Objective 1a: Estimate core passage metrics

Adult trap efficiency (*ATE*) for Merwin Dam is the percentage of actively migrating adults that are caught in the Merwin fish trap. 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}, one of two metrics that have been developed in order to evaluate trap efficacy (the other being P_{EE}; see below). 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.

As a point of note, ATE_{test} calculated as described above represents a “raw” summary statistic, which does not account for sample size or mathematical properties of binomially distributed proportional data. Estimates of population level proportions based on samples, such as ATE_{test}, tend to miss the true population proportion (*ATE*) by one standard deviation of the true proportion, which can be thought of as the expected error amount (Dytham 2011). For samples of proportion data, this expected error is equivalent to the standard error (SE) of the estimate. As sample size increases, SE shrinks in proportion to the square root of sample size increase (Dallal 2012). Our method for accounting for sample size and presenting uncertainty of this and other estimates is described below.

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; i.e., fish detected at the trap entrance or any receivers upstream of the trap entrance are considered to have successfully passed the trap entrance), calculated as follows:

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

where:

T is the number of fish that enter the trap, regardless of whether they were eventually captured or returned back to the tailrace (i.e., exited the tailrace) as 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 T_i values equate to lower trap effectiveness:

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

All core metrics (ATE_{test}, P_{EE} and T_i) were estimated separately for each of the two release groups (Naïve and Non-Naïve) as well as for a ‘Total’ group of fish consisting of Naïve and Non-Naïve fish combined.

To account for Coho salmon returning to the Lewis River Hatchery, which are assumed to not display volitional passage behavior at Merwin Dam, a fourth summary metric was created, *adjusted-*ATE_{test} ($adjATE_{test}$). The $adjATE_{test}$ metric accounts for the number of fish captured at the Lewis River Hatchery that also entered the Merwin Dam tailrace ($M_{HatchRecap}$) by subtracting these fish from the number of fish entering Merwin Dam tailrace (M), calculated as follows:

$$adjATE_{test} = \frac{C}{M-M_{HatchRecap}} \qquad (Equation\ 4)$$

Observations (raw proportions) are presented in tables for the purposes of reporting and data summary. In addition, to generate informed estimates of core passage metrics, and to facilitate statistical comparisons between core metrics and targets, and comparisons of core metrics among groups, Bayesian methods were used to infer posterior probability distributions (posteriors) of core metric values for each group, using the Bolstad package (Curran & Bolstad 2018) within Program R (R Core Team 2018). Proportional data tend to exhibit binomial distributions, which are best modeled using beta prior probability distributions (priors). Given numerous operational, infrastructural, and environmental differences among previous study years, we elected to use uniform Bayes-Laplace (beta (1, 1)) priors, to minimize biasing current year's results with results from non-comparable years.

The result of these efforts is a series of posteriors for each core metric for each group. Importantly, posteriors contain all of the information (i.e., prior assumptions and data), and provide the complete inference from the Bayesian perspective, including statistical moments concerning central tendency and precision (Bolstad 2007). Thus, the posteriors are the source of Bayesian Credible Intervals (BCIs, aka Highest Density Intervals or HDIs), and form the basis of comparisons between metrics and targets, and among groups. HDIs are the Bayesian analog to frequentist Confidence Intervals (CIs), with the benefit that HDIs express precision as the probability of a value given the data, rather than vice versa, as is the case for frequentist CIs.

Objective 1b: Evaluate core passage metrics against performance standards

Core passage metrics were compared to performance standards by inferring precision of posterior estimates based on 95% HDIs. 95% HDIs were estimated for ATE_{test} values associated with each release group using the Bayesian posteriors derived as explained above. These 95% HDIs encompass the range of parameter values that are 95% most credible, given the priors and the data. After generating a 95% HDI, testing a hypothesis regarding threshold targets (i.e., comparing ATE_{test} to ATE_{target}) at 5% alpha rate simply amounts to comparing the target value to the HDI range, and determining if the target falls within the HDI. Additional insights were generated by determining the actual posterior probability density for ATE_{target} for each group.

Objective 1c: Test for temporal trends in ATE

To determine if *ATE* changes over time, generalized linear models (GLM) were used to model individual fish passage success based on release date. The GLMs used logistical regression with a binomial response variable, passage success, being either zero (not re-captured) or one (re-captured). Temporal trends were examined separately for Naïve and Non-Naïve fish, and separately for fish that entered the tailrace and for all fish released.

Objective 2: Determine if Coho salmon 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, 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 distinct zones: downstream, tailrace, and trap. The Bridge receiver separated downstream nodes from tailrace nodes, and the Entrance receiver separated tailrace nodes from trap nodes. Using these logical labels, the transition matrix created from the raw transition data were adjusted in the following ways:

- Downstream transitions were linearized.
    - e.g., (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.
    - e.g., (Boat Ramp→ Powerhouse South) became (Boat Ramp→Holding Pool; Holding Pool→Bridge; Bridge→ Powerhouse South), and likewise for the reverse.
- Transitions from the tailrace to the trap were forced to go through the Entrance receiver.
    - e.g., (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 the Bridge receiver, and then forcing them to enter the post through the Entrance receiver 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. 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;

- The difference between individual and instantaneous transition rates, which we define here as the milling index, *MI*

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

- 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.

To evaluate behavioral differences between Naïve and Non-Naïve fish, comparisons were made based on the following:

- Visualization of movements of Naïve and Non-Naïve fish using network diagrams
- Wilcoxon rank sum test comparing median number of sites visited between Naïve and Non-Naïve fish
- Transition rates and milling index of Naïve and Non-Naïve fish

Objective 3: Determine if Coho salmon 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 both visually and statistically analyze:

1) Median residence times per site; and

2) Total time spent by Coho salmon 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 effectively blanket 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 duration that Coho salmon are present in Merwin Dam tailrace, and compare this 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 to account for fish milling behavior, and to remain comparable with previous reports (Stevens et al. 2015; Caldwell et al. 2017; Drenner et al. 2017; 2018a; 2018b; 2018c). Estimates for tailrace passage time are presented for:

- All fish that entered the tailrace;
- Fish that entered the tailrace but not the trap;
- Fish that entered the trap but were not re-captured; and
- Fish that were re-captured.

In addition, tailrace passage times are presented separately for Naïve and Non-Naïve fish. A non-parametric Wilcoxon rank sum test was used to test if median tailrace passage times for Naïve and Non-Naïve fish were statistically different.

Objective 5: Describe the movement and behavior of tagged Coho salmon 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 detection site), 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 Coho salmon that are captured by the trap, as a function of individual fish energetic state, and rates of descaling, injury, and reflex impairment.

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. In addition to qualitative assessments, two additional methods were used to assess fish condition, measurement of fish energetic state and reflex impairments.

Individual fish energetic state was assessed by measuring muscle lipid content of fish prior to being released. Relationships with fish energetic state was evaluated for: a) release date (linear regression); b) release group (i.e., Naïve versus Non-Naïve fish; generalized linear models (GLMs)); and c) fate after release (i.e., trapped versus not trapped; Wilcoxon rank sum tests)

Reflex impairment was assessed for individual fish following RAMP protocols (see Raby et al. 2012); the resulting RAMP scores being a proportion of the five assessed reflexes that were impaired (e.g., the closer the value to one, the more reflexes were impaired). Descriptive statistics for RAMP scores are presented, however, no formal statistical tests were applied due to the small amount of RAMP score variability observed among individual fish.

RESULTS

Summary

From 21 September – 29 October 2018, 78 adult Coho salmon (36 females, 42 males; FL = 53 – 78 cm) were collected, implanted with radio tags, and released into the NF Lewis River below Merwin Dam to continue their upstream migrations to the Merwin Dam fish trap. Of those 78 tagged Coho salmon, regarding previous trap exposure, 63 were trap Non-Naïve fish and 15 were trap Naïve; regarding natal origin, 70 were HOR fish and eight were NOR fish (**Table 3**). The intent was to tag more NOR fish, but there were low numbers of NOR fish available. Therefore, HOR fish were tagged as surrogates to NOR fish.

Table 3. Matrix showing numbers of fish tagged and released by fish origin (i.e., NOR and HOR) and release group (i.e., Non-Naïve and Naïve). Totals are also shown.

Fish origin	Non-Naïve fish (*n*)	Naïve fish (*n*)	Total
HOR	58	12	70
NOR	5	3	8
total	63	15	

Below, we present summary results for all 78 fish tagged and released, including the distribution of unique detections among receivers for these fish (Figure 6), plus instances of tag shed, tag failure and mortalities. Summary data on individual fish and their detections are presented in Appendix A-3.

- Four fish shed (i.e., regurgitated) their radio tag but were later re-captured in the Merwin Dam fish trap and identified by PIT tag detection. Three fish were reported as mortalities found at locations on the NF Lewis River and within a tributary of the NF Lewis River.
    - *Tag sheds are accounted for in the core metrics presented herein (e.g., fish re-captured without detections in the trailrace or trap were added to total counts of fish that entered the tailrace and were trapped).*
- 77 fish (99% of total) were detected at least once somewhere within the detection array. The one fish not detected was a Non-Naïve fish that was eventually recaptured at the Merwin Fish Collection Facility.
- Five (6%) and four (5%) of the tagged fish were detected in the East Fork Lewis River and Cedar Creek, respectively. Five fish (6%) were detected at the furthest downstream site, the Lewis River Mouth site.

- Among radio telemetry sites with fish detections, the Lewis River Hatchery site detected the most fish (*n*=58). The trap Entrance site detected the fewest fish (*n*=3).
- 25 fish (32% of total) entered the Merwin Dam tailrace. Two of these were only detected at the Bridge site, and never further into the tailrace.
- 20 fish (26% of total) entered the trap (i.e., were detected at the Entrance site or further upstream), 100% of which were detected past the fyke at the base of Pool 2.
- **Note:** *Low numbers of fish detected at the Entrance site compared to upstream sites indicated fish passed the Entrance site without being detected. The trap entrance has high flows and no holding areas for fish, so fish presumably move quickly through this area, thereby avoiding detection on the Entrance receiver. To account for low detection efficiency at the Entrance receiver, fish are considered to have entered the trap after being detected on any receiver upstream of the Entrance receiver.*
- 17 fish (22% of total), comprising 8 females (22% of 36 tagged) and 9 males (21% of 42 tagged), were re-captured at the Merwin Dam Adult Fish Collection Facility.
  - Of note, three out of the eight NOR fish tagged and released were re-captured; all three were re-captured at the Merwin Dam Adult Fish Collection Facility, and none at Lewis River Hatchery.
- 16 fish (21% of total), comprising 7 females (19% of 36 tagged) and 9 males (21% of 42 tagged), were recaptured at the Lewis River Hatchery.
  - Of the 16 fish recaptured at the Lewis River Hatchery, nine (56%) were detected on the radio antenna site in the ladder leading into the Lewis River Hatchery (i.e., the LHL site).

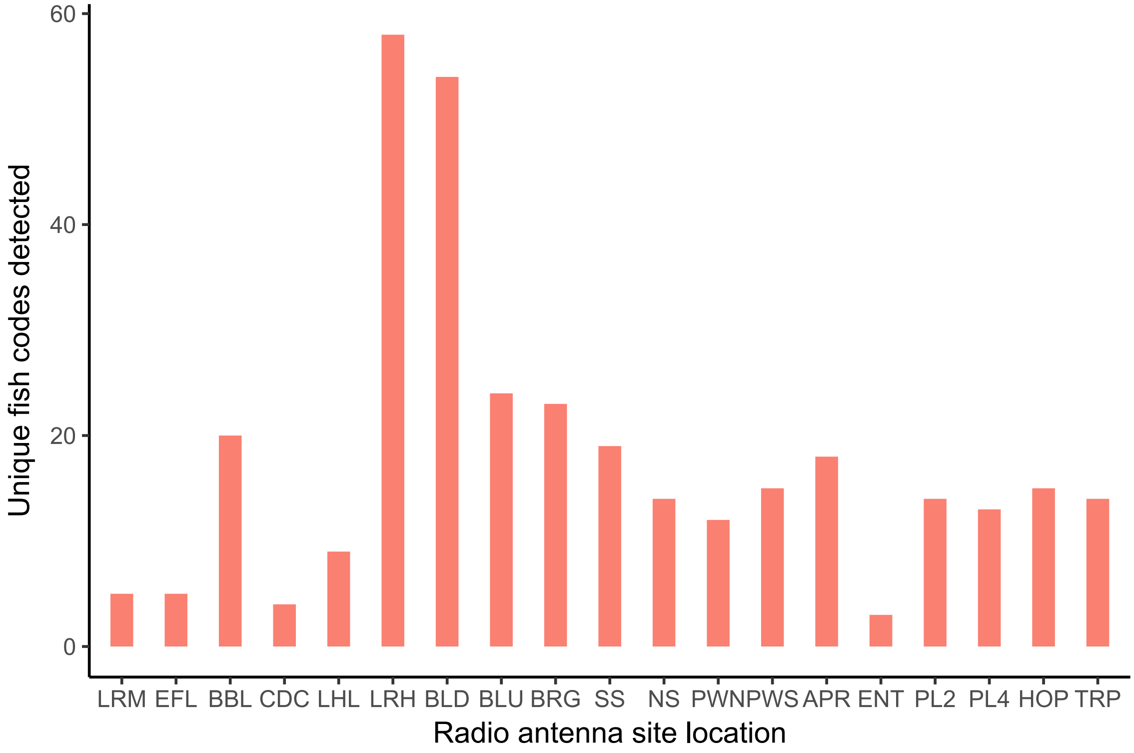

Figure 6. Numbers of unique fish codes (i.e., fish IDs) detected on each radio receiver site within the study area. Radio antenna sites are generally organized along the x-axis from furthest downstream site on the left to furthest upstream site on the right. See Figure 1, Figure 3, and Figure 4 for receiver locations. Abbreviations are given for sites as follows: LRM (Lewis River Mouth); EFL (East Fork Lewis); BBL (Bed & Breakfast); CDC (Cedar Creek); LRL (Lewis Hatchery Ladder); LRH (Lewis River Hatchery); BLD (Boat Launch Downstream); BLU (Boat Launch Upstream); BRG (Bridge); SS (South Shore); NS (North Shore); PWN (Powerhouse North); PWS (Powerhouse South); APR (Approach); ENT (Entrance); PL2 (Pool 2); PL4 (Pool 4); HOP (Hopper); and TRP (Trap).

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%

Objective 1a: Estimate core passage metrics

During the 2018 study season, a total of 78 tagged Coho salmon were tagged and tracked as part of this study (N), representing both Naïve and Non-Naïve release groups, of which 25 were detected within the Merwin Dam tailrace (M), 20 were detected entering the Merwin Dam trap (T), and 17 were ultimately captured (C) at the Merwin Fish Collection Facility. These counts provide the basis for raw estimation of the core metrics of trap attraction, P_{EE} = 73% (20/25), trap retention, ATE_{test} = 68% (17/25), and trap ineffectiveness, T_i = 15% (7/20; see Table 4).

Out of the 63 tagged Non-Naïve fish, 23 (37%) entered the tailrace, 19 entered the trap (raw P_{EE} = 75%) and 16 were recaptured at the Merwin Fish Collection Facility (raw ATE_{test} = 70%). Out of the 15 tagged Naïve fish, 2 (13%) entered the tailrace, one of which entered the trap (raw P_{EE} = 50%) and was successfully recaptured at the Merwin Fish Collection Facility (raw ATE_{test} = 50%).

A total of 11 Non-Naïve fish were recaptured at Lewis River Hatchery, two of which previously entered the Merwin Dam tailrace, which results in an *adjusted-*ATE_{test} of 76%. A total of five Naïve fish were recaptured at the Lewis River Hatchery, but none of these entered the tailrace at Merwin Dam, and thus, the *adjusted-*ATE_{test} for Naïve fish equals the raw ATE_{test} of 50%. The *adjusted-*ATE_{test} for Non-Naïve and Naïve fish combined (i.e., the Total group) was 74%.

Table 4. Summary of passage metrics for tagged Coho salmon approaching the tailrace of Merwin Dam and that entered the Lewis River Hatchery during Fall 2018. Raw ATE_{test} values, which are comparable to previous ATE_{test} estimates presented for Coho salmon at Merwin Dam, are bolded.

Metric	**Naïve**	**Non-Naïve**	**Total**
Tagged Fish (N)	15	63	78
Entered the Merwin tailrace (M)	2	23	25
Entered the Trap (T)	1	19	20
Captured (C)	1	16	17
Raw Trap Entrance Efficiency ($P_{EE} = \frac{T}{M}$)	50%	75%	73%
Raw Collection Efficiency ($ATE_{test} = \frac{C}{M}$)	**50%**	**70%**	**68%**
Raw Trap Ineffectiveness ($T_i = \frac{T-C}{T}$)	0%	16%	15%
Captured at Lewis River Hatchery	5	11	16
Hatchery recaptures detected in Merwin tailrace ($M_{HatchRecap}$)	0	2	2
Adjusted-ATE_{test} ($adjATE_{test} = \frac{C}{M-M_{HatchRecap}}$)	*50%*	*76%*	*74%*

Statistical evaluations of core passage metrics using Naïve fish alone and statistical comparisons between Naïve and Non-Naïve release groups are inappropriate due to the low sample sizes in the Naïve fish that entered the tailrace (n=2). Therefore, quantitative results for core metrics focus on either Non-Naïve fish alone or a combination of both Naïve and Non-Naïve release groups. However, behavioral comparisons between Naïve and Non-Naïve fish are presented and discussed below to provide biological context for differences between these two release groups.

Objective 1b: Evaluate core passage metrics against performance standards

Core passage metrics (i.e., ATE_{test}) were evaluated against performance standards (i.e., ATE_{target}) for the Non-Naïve release group and for all fish combined (i.e., a 'Total' group that included both Naïve and Non-Naïve fish). Naïve fish were excluded from comparisons due to low sample sizes of Naïve fish that entered the tailrace (n=2).

Non-Naïve:

The Bayesian posterior ATE_{test} estimate for the Non-Naïve fish that reached the tailrace (n = 23) was 68% (95% HDI = 49-84%). There was a nearly 100% posterior probability that the true *ATE* value of the parent population for this group was < 98%. That is, there was an exceedingly small (<0.0001%) posterior probability that the true *ATE* of the parent population met or exceeded the target.

The Bayesian posterior $adjATE_{test}$ estimate for the Non-Naïve fish, which excluded two fish captured at the Lewis River Hatchery from the total number of fish that reached the tailrace, was 74% (95% HDI = 55-89%).

Total:

The Bayesian posterior ATE_{test} estimate for the Total number of fish that reached the tailrace (n = 25) was 67% (95% HDI = 48-83%). There was a nearly 100% posterior probability that the true *ATE* value of the parent population for this group was < 98%. That is, there was an exceedingly small (<0.0001%) posterior probability that the true *ATE* of the parent population met or exceeded the target.

The Bayesian posterior $adjATE_{test}$ estimate for the Total group of fish, which excluded two fish captured at the Lewis River Hatchery from the total number of fish that reached the tailrace, was 72% (95% HDI = 53-87%).

Objective 1c: Test for temporal trends in ATE

Among release groups, raw ATE_{test} values ranged from 0 – 100% (Table 5). ATE_{test} values weighted by the number of fish that entered the tailrace showed no apparent trend in ATE over time (Table 5).

Table 5. Passage metrics summarized by release date for 2018. See Table 4 for explanation of notation. Note: Naïve and Non-Naïve release groups were combined for this table.

Release Date	***N***	***M***	***T***	***C***	**Group raw ATE_{test} (%)**	**Weighted ATE_{test} (%)**
9/21/2018	5	4	3	2	50%	8%
9/26/2018	5	4	3	3	75%	12%
9/28/2018	5	2	2	1	50%	4%
10/11/2018	12	5	4	4	80%	16%
10/16/2018	20	4	4	3	75%	12%
10/18/2018	7	3	2	2	67%	8%
10/25/2018	9	1	1	1	100%	4%
10/10/2018	2	0	0	0	*N/A*	*N/A*
10/17/2018	2	0	0	0	*N/A*	*N/A*
10/22/2018	3	1	1	1	100%	4%
10/24/2018	6	0	0	0	*N/A*	*N/A*
10/29/2018	2	1	0	0	0%	0%
Total:	**78**	**25**	**20**	**17**	**See Table 4**	

Results from binomial GLMs indicated there was no significant effect of release date on raw re-capture probability, either using only fish that entered the tailrace (*df* = 24, *p* = 0.51, not shown) or using all released fish (*df* = 77, *p* = 0.14; Figure 7).

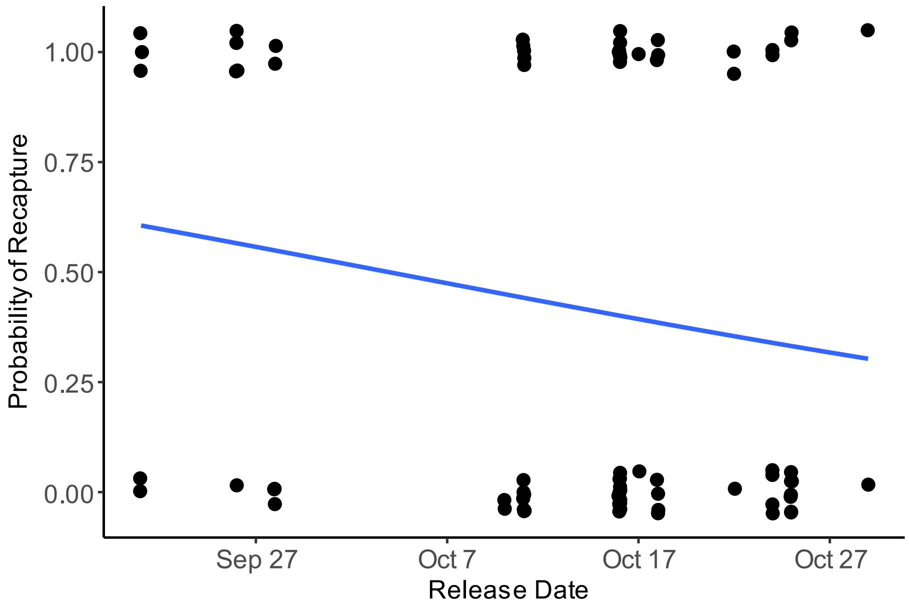

Figure 7. The raw probability of re-capture for individual fish, plotted as a function of release date. Solid circles represent all individual fish released (Non-Naïve and Naïve release groups). Blue line indicates the predicted probability of re-capture across release date based on logistic regression. All released fish were included in this figure not just those fish that reached the tailrace.

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

To facilitate comparisons with previous reports and ease of interpretation, we present Objective 2 results in two sections. First, results for Non-Naïve fish are presented, which are comparable to results from previous studies. Next, we present results comparing Naïve and Non-Naïve fish to explore behavioral difference between these two groups of fish.

Non-Naïve fish

A visual analysis of the network diagram for Non-Naïve Coho salmon movements throughout the study area illustrates the tendency of fish to move widely within the tailrace (Figure 8). Key findings include:

1) There is no clear preference of fish entering the tailrace upstream of the Bridge receiver for either the South Shore or the North Shore of the tailrace (grey lines leaving Bridge and pointing towards SS and NS are similar in shading and thickness in Figure 8).
2) The most frequent pathway that resulted in a detection at just outside of the entrance to the trap was from the South Shore (grey lines pointing towards Approach are darkest from SS in Figure 8).
3) The most frequent movement that fish made was from the Boat Launch Downstream site to the Lewis River Hatchery site (dark grey line pointing from the BLD site to the LRH site in Figure 8).
4) Within the tailrace, individuals exhibited the most milling behaviors (blue lines in Figure 8) between the South Shore and Approach sites, followed by between the Bridge ↔ North Shore ↔ Powerhouse North sites.
5) Within the trap, most milling occurred between the Hopper ↔ Pool 4 sites (blue lines in Figure 8).

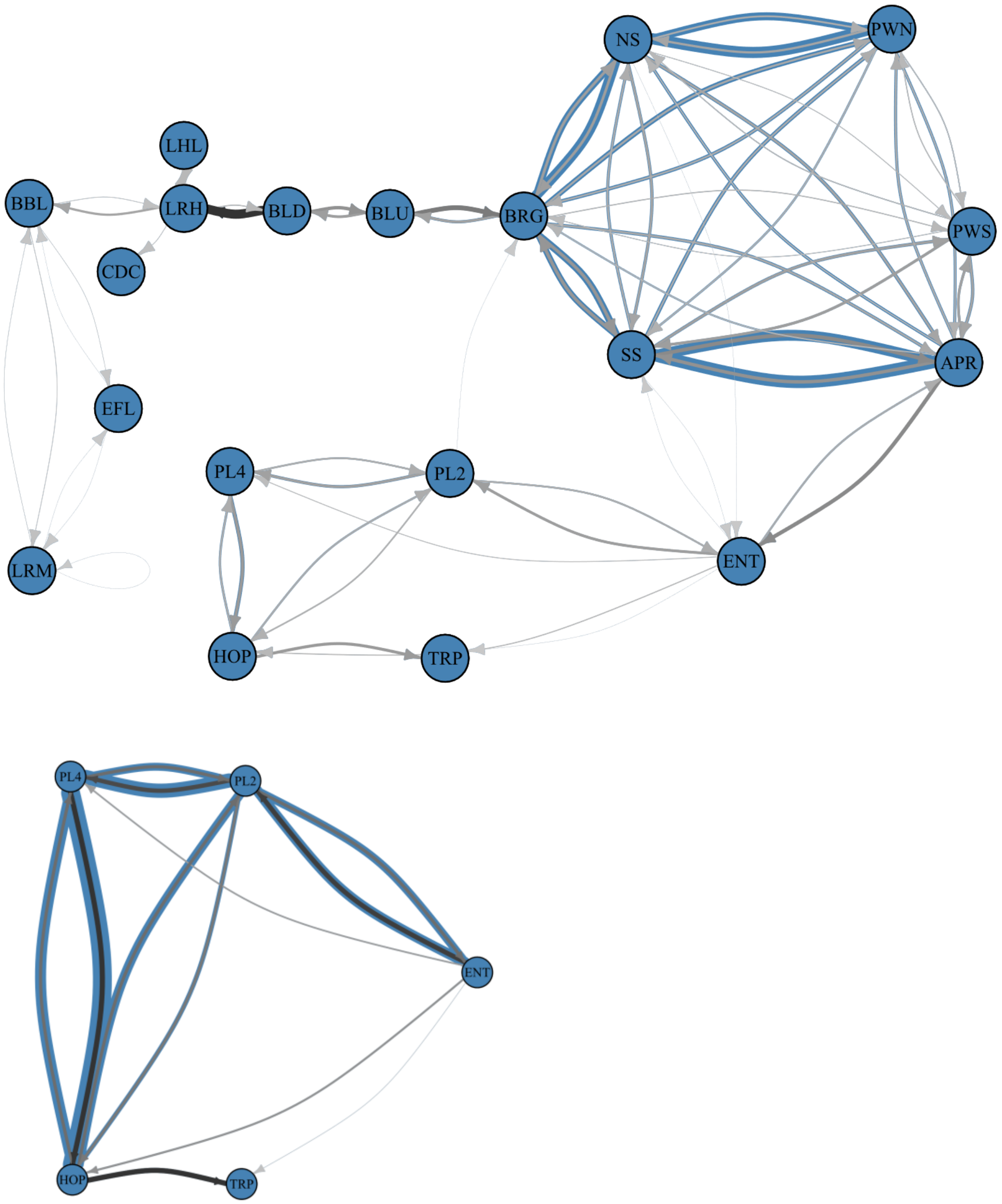

Figure 8. Network diagram of fish movement within study area. Path thickness and color are scaled based on the total number of individual fish traveling the paths (thicker paths represent a higher number of fish taking the path at least one time across their detection history). Grey paths are scaled to represent the total number of fish that traveled between sites (individuals as the sample unit). 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. Abbreviations are given for sites as follows: LRM (Lewis River Mouth); EFL (East Fork Lewis); BBL (Bed & Breakfast); CDC (Cedar Creek); LRL (Lewis Hatchery Ladder); LRH (Lewis River Hatchery); BLD (Boat Launch Downstream); BLU (Boat Launch Upstream); BRG (Bridge); SS (South Shore); NS (North Shore); PWN (Powerhouse North); PWS (Powerhouse South); APR (Approach); ENT (Entrance); PL2 (Pool 2); PL4 (Pool 4); HOP (Hopper); and TRP (Trap).

Next, we generated a heat map in matrix form, depicting color-coded probabilities of fish moving from one site to another (Figure 9). 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 at the Entrance receiver. Other results shown in the heat map figure include the following:

1) After release, fish were most likely to be next detected at the Boat Launch Downstream (with a probability of 73%) and the Boat Launch Upstream site (with a probability of 16%) sites.
2) Once a fish has progressed up to the Bridge site, it has an equal probability (28%) of next being detected at the either the South Shore or North Shore sites. From the Bridge site, there was only an 11% probability of a fish moving to any site downstream.
3) There was a high probability of fish being next detected at the nearest upstream site when fish were at Pool 4 (with a probability of 71%) and the Boat Launch Upstream (with a probability of 66%) sites.
4) There was a high probability of fish exiting the system (e.g. not being detected again) when at the Cedar Creek site (with a probability of 100%) or the Lewis River Hatchery (with a probability of 53%).
5) Fish that entered the East Fork Lewis River site had equal probabilities (33%) of being next detected further downstream at the Lewis River Mouth, further upstream at the Bed & Breakfast site, or exiting the system.
6) Once a fish has nosed into the trap at the Entrance receiver, there was a 43% probability of being next detected upstream in Pool 2 and a 38% probability of being next detected outside of the trap entrance at the Approach site.
7) Once inside the trap and detected in Pool 2, there was a 68% probability of the fish being detected further into the trap, and a 30% probability of fish being detected downstream at the Entrance site.

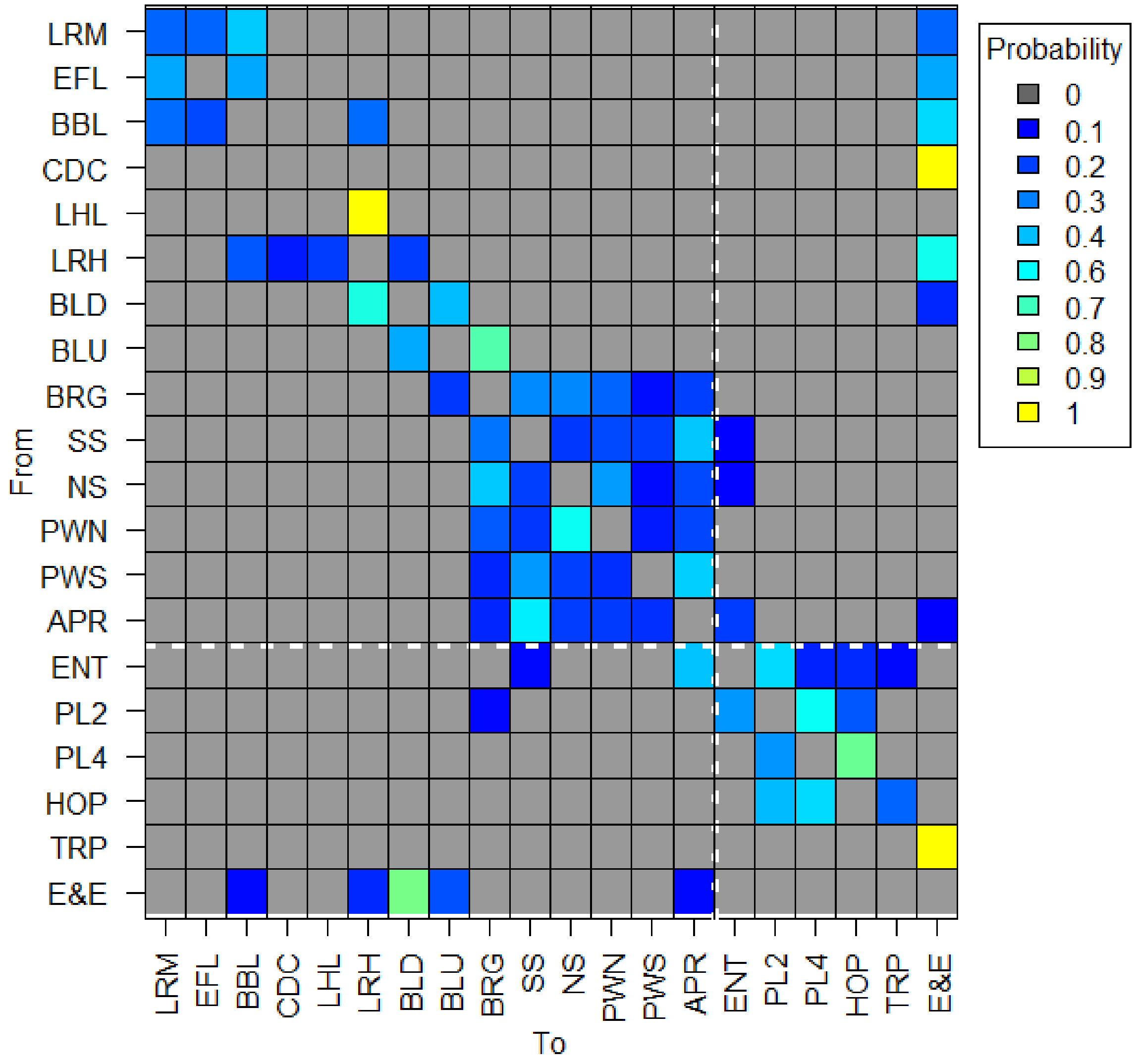

Figure 9. Heat map of the transition probabilities of fish moving from an origin site to all potential destination sites. Each row sums to a probability of 1. Dashed reference lines are added between the Approach and Entrance receivers to show the distinction of a fish being located within or outside of 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). Abbreviations are given for sites as follows: LRM (Lewis River Mouth); EFL (East Fork Lewis); BBL (Bed & Breakfast); CDC (Cedar Creek); LRL (Lewis Hatchery Ladder); LRH (Lewis River Hatchery); BLD (Boat Launch Downstream); BLU (Boat Launch Upstream); BRG (Bridge); SS (South Shore); NS (North Shore); PWN (Powerhouse North); PWS (Powerhouse South); APR (Approach); ENT (Entrance); PL2 (Pool 2); PL4 (Pool 4); HOP (Hopper); and TRP (Trap).

By comparing the number of unique site visits by each fish (Figure 10), it is apparent that fish that are trapped (i.e., re-captured at the Merwin Fish Collection Facility) visited more sites (mean = 100.2, median = 25) compared to fish that were not trapped (mean = 13.5, median = 2). Fish that were trapped visited on average 87 more sites before being trapped compared to fish that failed to be trapped.

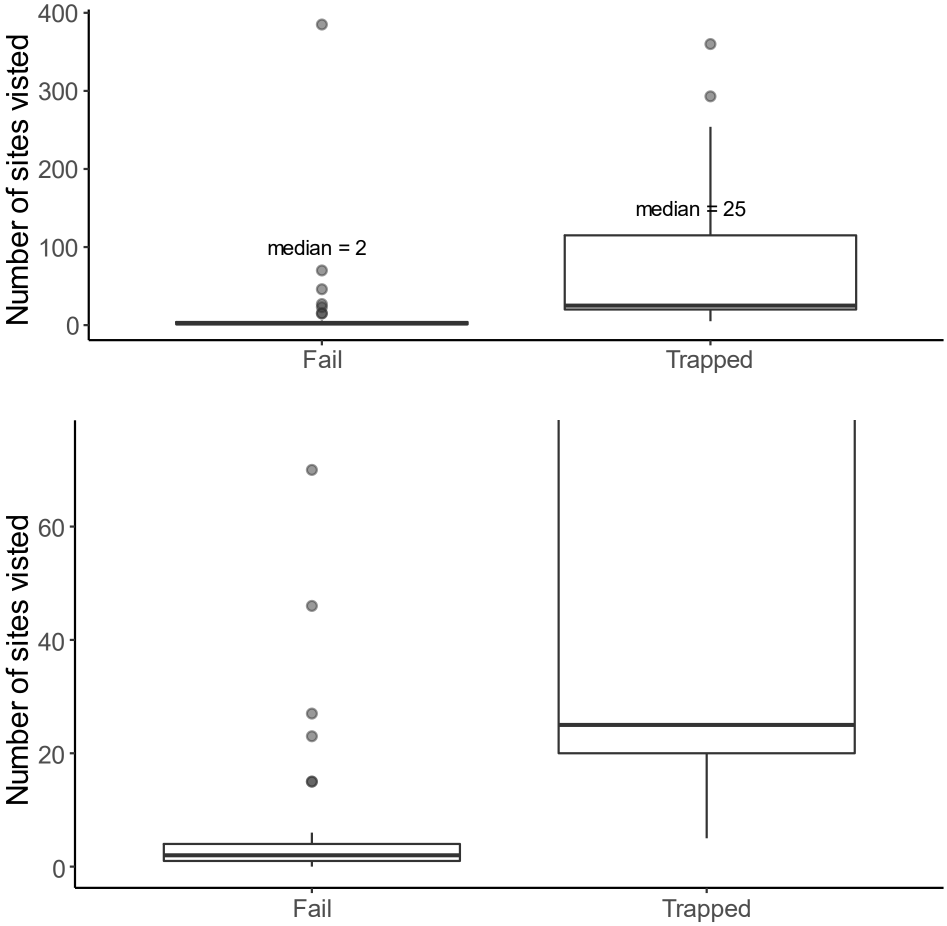

Figure 10. Number of sites visited before being re-captured (Trapped) at the Merwin Fish Collection Facility or not re-captured before the end of the study (Fail). The top figure shows the full range of data and the bottom figure zooms in to better show the quantiles and median values for the Fail group.

In general, fish tended to move upstream through the telemetry array study area from the Boat Launch Upstream site to the South Shore of the tailrace, with most sites having a forward transition probability greater than 50% ($p \geq 0.50$). In contrast, fish tended to move downstream from the Boat Launch Downstream site (Table 6).

Of note, all fish that were eventually re-captured at the Merwin Fish Collection Facility never reached sites further downstream than the Boat Launch Downstream site (note – these results are for Non-Naïve fish released in between the Boat Launch sites) (Table 6). Fish that were not re-captured at the Merwin Fish Collection Facility tended to move downstream from most sites in the telemetry array (Table 6).

Additional results based on transition probabilities presented in Table 6 included:

- In the tailrace, fish tended to mill along the North Shore.
- Fish had the greatest probability of transitioning to the next upstream receiver when fish were detected at the Bridge site.
- Fish had the lowest probability of transitioning to the next upstream receiver when fish were detected at the Lewis River Hatchery site.
- The Hopper and Entrance sites exhibited the greatest degree of milling, as evidenced by the greatest *MI* values for both collected and not-collected fish.

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}. Positive values of *MI* suggest that fish tend not to move forward from that location. Site specific P_{single} or P_{all} <0.5 are shaded blue, and *MI* >0.000 are shaded green. P_{single} *and* P_{all} values are provided for fish not collected (i.e., *Fail*), for fish collected (i.e., *Pass*), and for collected and not collected fish combined (i.e., *Total*). For site abbreviations, see Table 2. Abbreviations are given for sites as follows: LRM (Lewis River Mouth); BBL (Bed & Breakfast); LRH (Lewis River Hatchery); BLD (Boat Launch Downstream); BLU (Boat Launch Upstream); BRG (Bridge); SS (South Shore); NS (North Shore); PWN (Powerhouse North); PWS (Powerhouse South); APR (Approach); ENT (Entrance); PL2 (Pool 2); PL4 (Pool 4); HOP (Hopper); and TRP (Trap).

Receiver	$P_{single, Fail}$ **(not collected)**	$P_{all, Fail}$ **(not collected)**	MI_{Fail}	$P_{single, Pass}$ **(collected)**	$P_{all, Pass}$ **(collected)**	MI_{Pass}	P_{single} **(collected and not collected)**	P_{all} **(collected and not collected)**	MI_{Total}
LRM	0.400	0.400	0.000	NA	NA	NA	0.400	0.400	0.000
BBL	0.214	0.214	0.000	NA	NA	NA	0.214	0.214	0.000
LRH	0.093	0.121	-0.028	NA	NA	NA	0.093	0.121	-0.028
BLD	0.098	0.210	-0.112	1.000	1.000	0.000	0.246	0.372	-0.126
BLU	0.412	0.424	-0.012	0.875	0.854	0.021	0.636	0.662	-0.026
BRG	0.682	0.844	-0.163	0.895	0.909	-0.014	0.817	0.891	-0.074
SS	0.563	0.644	-0.081	0.651	0.670	-0.018	0.627	0.662	-0.034
NS	0.462	0.479	-0.018	0.531	0.478	0.053	0.511	0.479	0.033
PWN	0.182	0.161	0.021	0.192	0.133	0.059	0.189	0.139	0.050
PWS	0.143	0.455	-0.312	0.310	0.392	-0.082	0.278	0.406	-0.128
APR	0.176	0.109	0.067	0.298	0.124	0.173	0.266	0.119	0.147
ENT	0.600	0.480	0.120	0.762	0.686	0.076	0.710	0.600	0.110
PL2	0.556	0.455	0.101	0.722	0.792	-0.069	0.667	0.686	-0.019
PL4	0.400	0.684	-0.284	0.688	0.714	-0.027	0.619	0.706	-0.087
HOP	0.000	0.000	0.000	0.520	0.271	0.249	0.448	0.200	0.248

When evaluating transition probabilities at each site to determine how fish moved through the system, it becomes apparent that non-recaptured fish tended to move further downstream from the tailrace sites (Figure 11). In contrast, and as noted above, no re-captured fish were detected further downstream than the Boat Launch Downstream site.

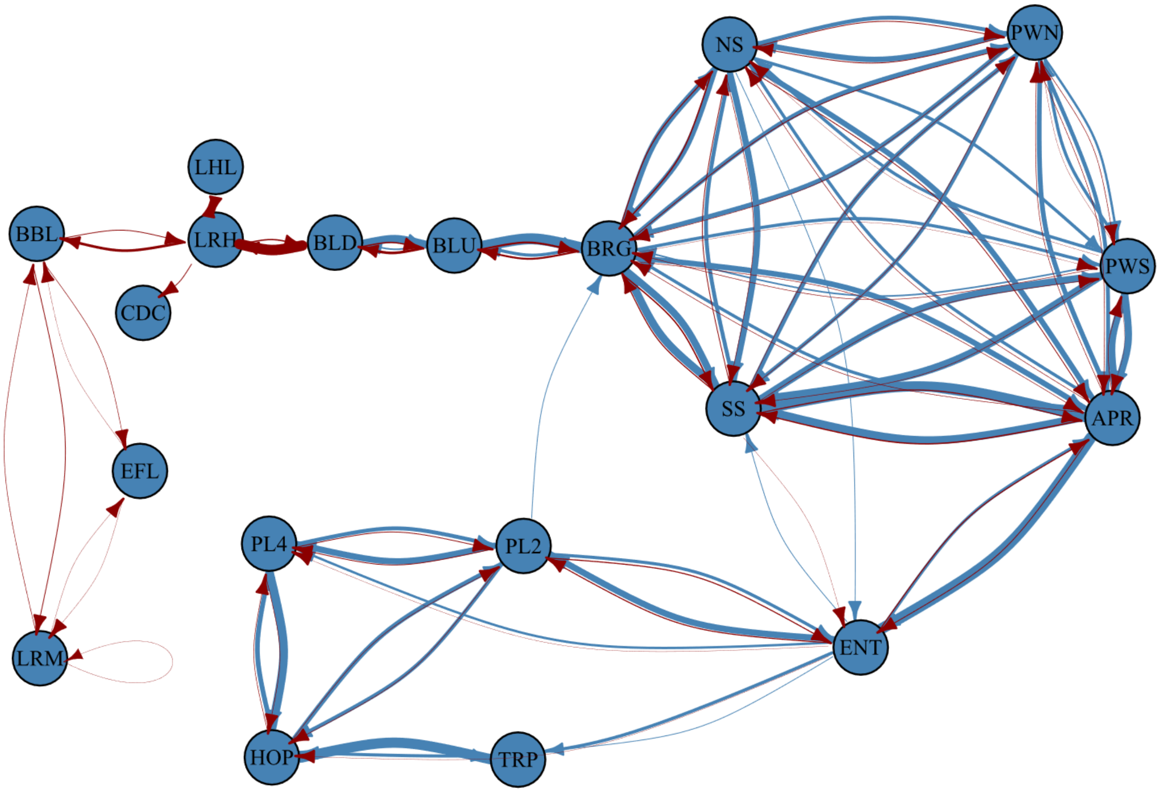

Figure 11. Network diagram of fish movement within the study area at Merwin Dam grouped by fish that ultimately are re-captured (blue) or failed to be re-captured (red) from 2018. Path thickness and color are scaled based on the total number of transitions which occurred between sites with fish as the sample unit. This graphic depicts the movements of 63 fish; 13 that were successfully re-captured (i.e., last detected at Trap) and 50 that were unsuccessful. This figure does not include movements of fish that experienced tag shed or tag failure. Abbreviations are given for sites as follows: LRM (Lewis River Mouth); EFL (East Fork Lewis); BBL (Bed & Breakfast); CDC (Cedar Creek); LRL (Lewis Hatchery Ladder); LRH (Lewis River Hatchery); BLD (Boat Launch Downstream); BLU (Boat Launch Upstream); BRG (Bridge); SS (South Shore); NS (North Shore); PWN (Powerhouse North); PWS (Powerhouse South); APR (Approach); ENT (Entrance); PL2 (Pool 2); PL4 (Pool 4); HOP (Hopper); and TRP (Trap).

Comparisons between Non-Naïve and Naïve fish

Comparisons of transition probabilities at each site between Naïve and Non-Naïve fish indicated Naïve fish had fewer downstream movements from the Boat Launch Downstream, Bridge and after entering the trap compared to Non-Naïve fish (Figure 12). Caution should be taken when comparing Naïve and Non-Naïve fish movements within the tailrace due to low numbers of Naïve fish that entered the tailrace (n=2).

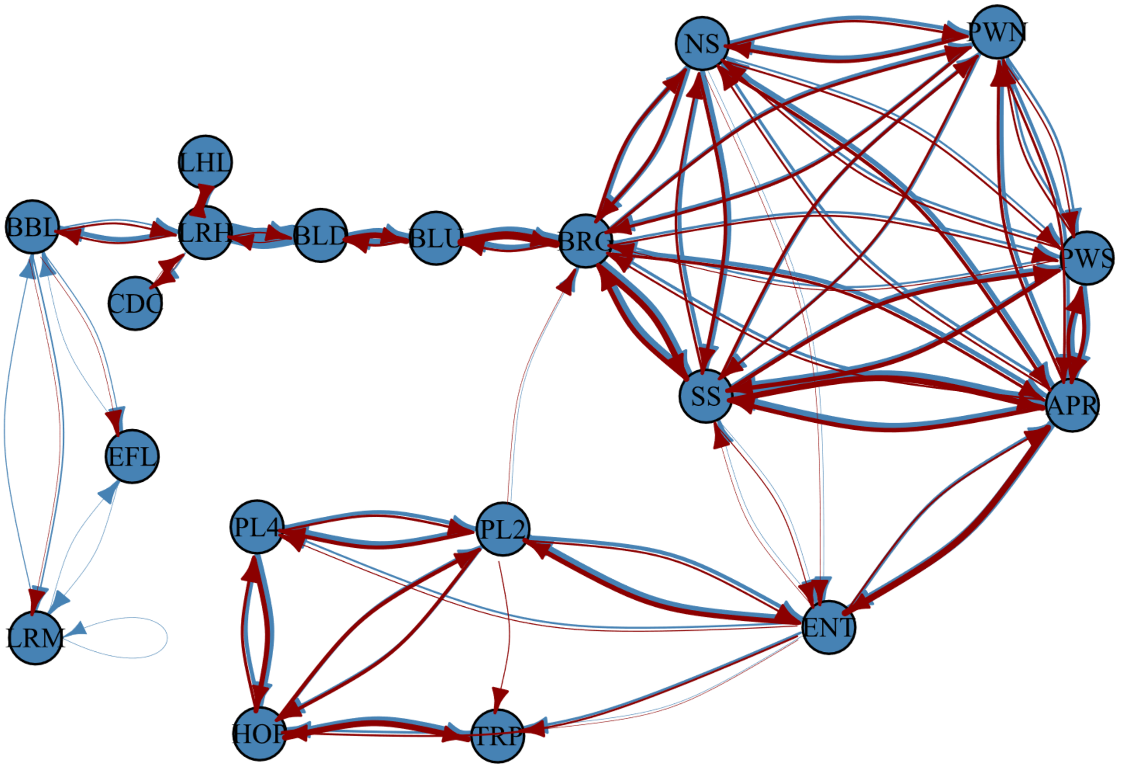

Figure 12. Network diagram of fish movement within the study area at Merwin Dam grouped by Naïve (red) or Non-Naïve (blue) release groups from 2018. Path thickness and color are scaled based on the total number of transitions which occurred between sites with fish as the sample unit. This graphic depicts the movements of 77 fish including 14 Naïve fish and 63 Non-Naïve fish. This figure does not include movements of fish that experienced tag shed or tag failure. Abbreviations are given for sites as follows: LRM (Lewis River Mouth); EFL (East Fork Lewis); BBL (Bed & Breakfast); CDC (Cedar Creek); LRL (Lewis Hatchery Ladder); LRH (Lewis River Hatchery); BLD (Boat Launch Downstream); BLU (Boat Launch Upstream); BRG (Bridge); SS (South Shore); NS (North Shore); PWN (Powerhouse North); PWS (Powerhouse South); APR (Approach); ENT (Entrance); PL2 (Pool 2); PL4 (Pool 4); HOP (Hopper); and TRP (Trap).

Statistical comparisons for the numbers of sites visited before capture between Naïve and Non-Naïve fish were inappropriate due to the low sample size of Naïve fish that were re-captured (n=1). Thus, we caution interpretations of the comparisons that are visually presented in Figure 13. The single Naïve fish that was recaptured visited 9 sites prior to being re-captured; Non-Naïve fish visited over 100 sites on average prior to being re-captured (Figure 13).

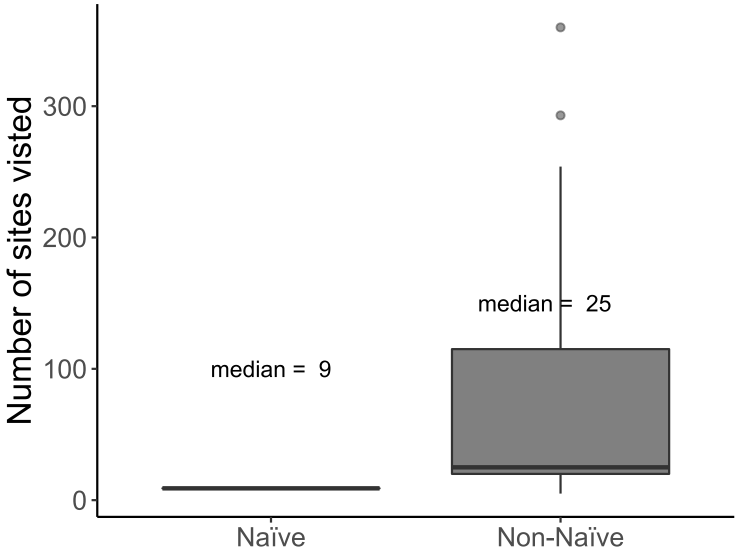

Figure 13. Number of sites visited before being trapped for Naïve and Non-Naïve fish. Note that only one Naïve fish was recaptured (i.e., n=1) so we caution interpretation of the data visually presented.

Compared to Non-Naïve fish, Naïve fish generally had higher probabilities of moving forward from the Boat Launch sites and sites within the trap (Table 7). The locations where fish tended to mill were the same between Naïve and Non-Naïve fish (Table 7).

Table 7. 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}. Positive values of *MI* suggest that fish tend not to move forward from that location. Site specific P_{single} or P_{all} <0.5 are shaded blue, and *MI* >0.000 are shaded green. P_{single} *and* P_{all} values are provided for Naïve and Non-Naïve fish. For site abbreviations, see Table 2. Abbreviations are given for sites as follows: LRM (Lewis River Mouth); BBL (Bed & Breakfast); LRH (Lewis River Hatchery); BLD (Boat Launch Downstream); BLU (Boat Launch Upstream); BRG (Bridge); SS (South Shore); NS (North Shore); PWN (Powerhouse North); PWS (Powerhouse South); APR (Approach); ENT (Entrance); PL2 (Pool 2); PL4 (Pool 4); HOP (Hopper); and TRP (Trap).

Receiver	**P_{single} (Non-Naïve)**	**P_{all} (Non-Naïve)**	**$MI_{Non\text{-}Naïve}$**	**P_{single} (Naïve)**	**P_{all} (Naïve)**	**$MI_{Naïve}$**
LRM	0.400	0.400	0.000	0.000	0.000	0.000
BBL	0.214	0.214	0.000	0.444	0.444	0.000
LRH	0.093	0.121	-0.028	0.150	0.150	0.000
BLD	0.246	0.372	-0.126	0.800	0.870	-0.070
BLU	0.636	0.662	-0.026	0.762	0.804	-0.042
BRG	0.817	0.891	-0.074	0.875	0.905	-0.030
SS	0.627	0.662	-0.034	0.651	0.664	-0.013
NS	0.511	0.479	0.033	0.548	0.481	0.068
PWN	0.189	0.139	0.050	0.192	0.133	0.059
PWS	0.278	0.406	-0.128	0.296	0.380	-0.084
APR	0.266	0.119	0.147	0.295	0.124	0.172
ENT	0.710	0.600	0.110	0.773	0.694	0.078
PL2	0.667	0.686	-0.019	0.773	0.808	-0.035
PL4	0.619	0.706	-0.087	0.667	0.708	-0.042
HOP	0.448	0.200	0.248	0.462	0.245	0.217

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

Tailrace & trap behavior

Once in the tailrace, there was no clear distinction between Coho salmon’s use of the south side versus the north side of the tailrace based on similar numbers, median residence times, and total times at sites along both the south side and the north side of the tailrace (Figure 14; Figure 15). Evaluation of fish behaviors within the tailrace revealed the following observations:

1) Fish spent slightly more time milling between South Shore and Approach receivers along the south side of the tailrace compared to the north side of the tailrace, based on higher numbers of visits to the South Shore and Approach sites compared to the North Shore and Powerhouse North sites.
2) Fish spent the most time holding at the Bridge site within the tailrace based on the relativley high median residence times and high total time spent at this site.
3) Fish were not frequently detected at the Entrance site, likley a result of high flows through this area and no locations for fish to hold.
4) Once in the trap, fish spent the most time holding inside Pool 2, Pool 4, and the Hopper sites, based on the relativley high median residence times and low number of site visits at these sites.
5) Fish did not spend a large amount of time holding at the Powerhouse South site, based on low median residence time, low numbers of visits, and low total time spent at this sites.
6) Behavioural trends were generally similar between Naïve and Non-Naïve fish; however, small sample sizes of Naïve fish (n=2) should be noted.

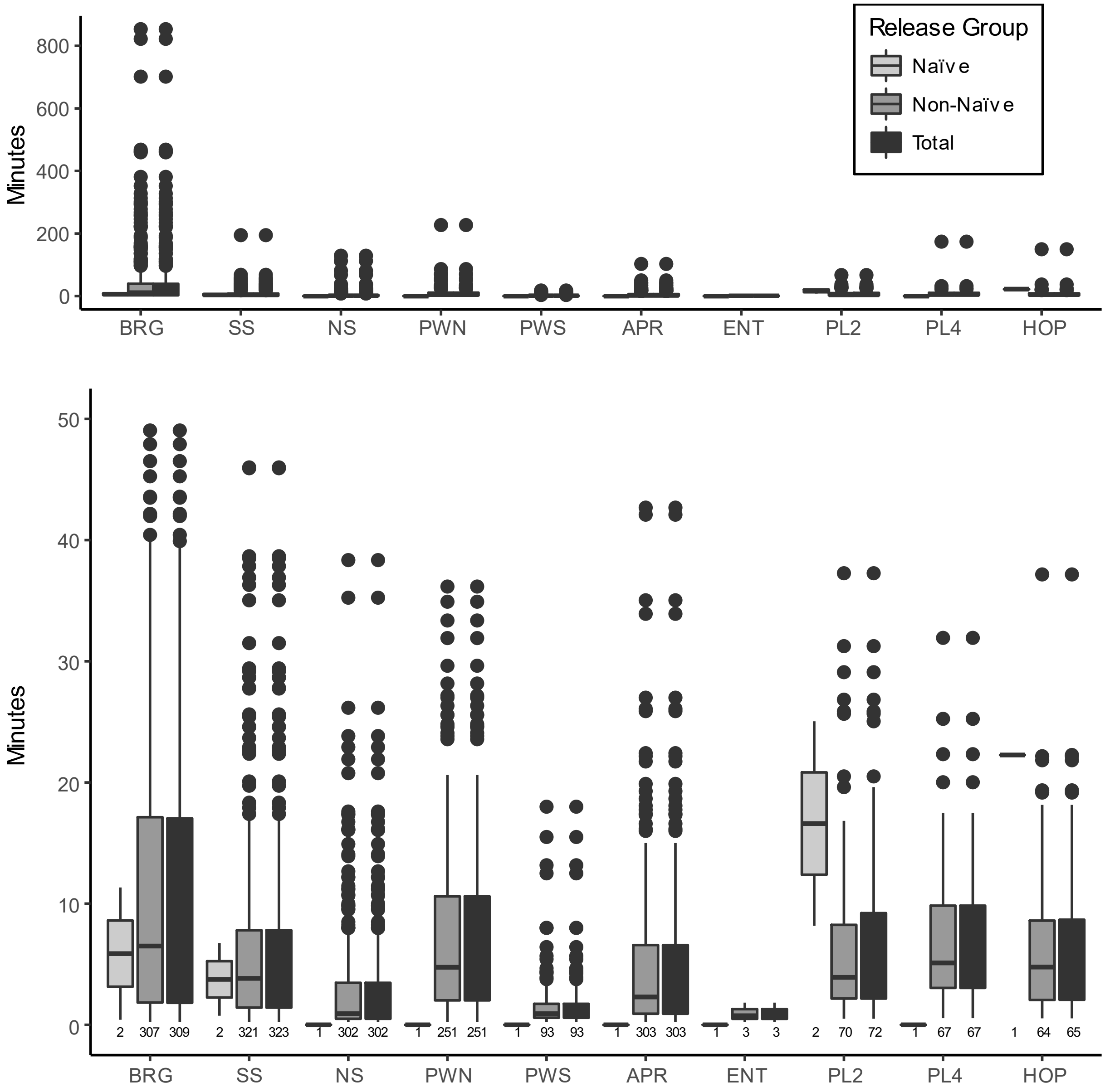

Figure 14. Median residence times by sites in the tailrace and trap. The top figure shows the full range of data, including outliers (closed circles), while the bottom figure zooms in to show the box and whisker plots, focusing on inter-quartile range. Data are separated by release group. Note: The Naïve release group had lower sample sizes (n=2) than the Non-Naïve release group (n=23), therefore, direct comparisons of residence times at each site between release groups is not appropriate. Number of visits is displayed below boxplots. (*Caveat: these data are not scaled based on the detection ranges of each site.*) Abbreviations are given for sites as follows: BRG (Bridge); SS (South Shore); NS (North Shore); PWN (Powerhouse North); PWS (Powerhouse South); APR (Approach); ENT (Entrance); PL2 (Pool 2); PL4 (Pool 4); HOP (Hopper); and TRP (Trap).

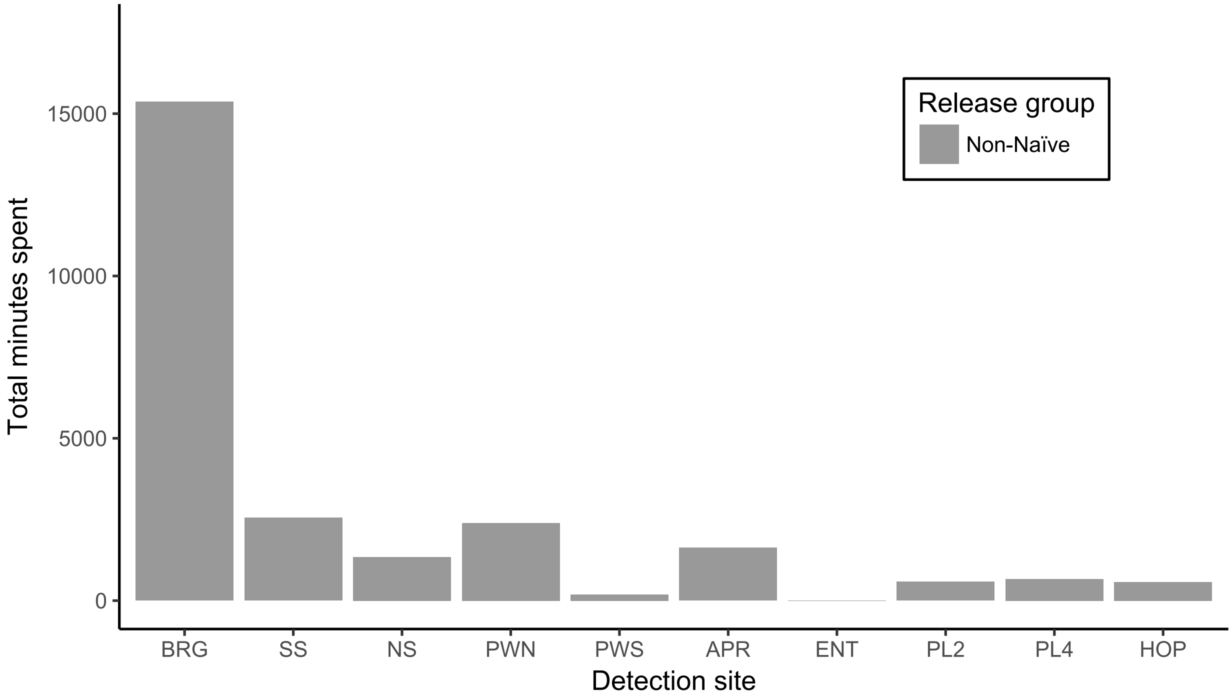

Figure 15. Total time spent by Non-Naïve Coho salmon in each site in the tailrace and trap. Note: Naïve fish were excluded from the figure due to low sample sizes of Naïve fish (n=2) that entered the tailrace. *Caveat: these data are not scaled based on the detection ranges of each site*. Abbreviations are given for sites as follows: BRG (Bridge); SS (South Shore); NS (North Shore); PWN (Powerhouse North); PWS (Powerhouse South); APR (Approach); ENT (Entrance); PL2 (Pool 2); PL4 (Pool 4); HOP (Hopper); and TRP (Trap).

Downstream behavior

At locations downstream of the tailrace, fish spent the most time holding at the Lewis River Hatchery, based on a low number of detections, high median residence, and total time spent at this location (Figure 16). Three fish were responsibe for an extremely large amount of median residence time at the Cedar Creek site (Figure 16), likley because these fish died or shed tags within the detection radius of that site. Naïve fish spent more time holding at the Lewis River Hatchery site compared to Non-Naïve fish based on low number of sites visits and high median residence time for Niave fish compared to Non-Naïve fish (Figure 16).

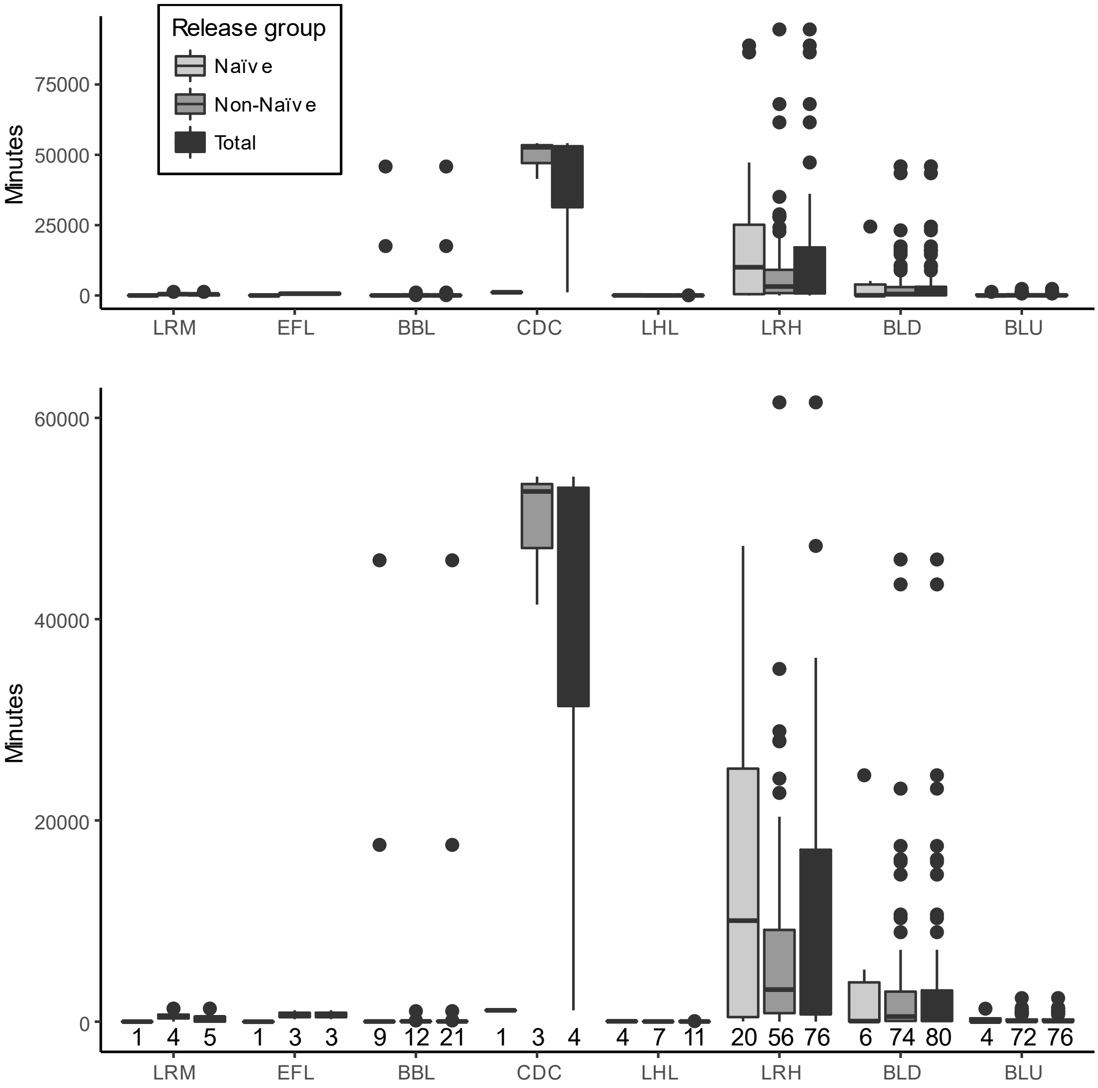

Figure 16. Median residence times for downriver sites. The top figure shows the full range of data, including outliers, while the bottom figure zooms in to show the box and whisker plots, focusing on inter-quartile range. Sample size (n) is displayed below the box plot for each site. *Caveat: these data are not scaled based on the detection ranges of each site*. Abbreviations are given for sites as follows: LRM (Lewis River Mouth); EFL (East Fork Lewis); BBL (Bed & Breakfast); CDC (Cedar Creek); LRL (Lewis Hatchery Ladder); LRH (Lewis River Hatchery); BLD (Boat Launch Downstream); and BLU (Boat Launch Upstream).

Both Naïve and Non-Naïve fish spent the most time at the Lewis River Hatchery site (Figure 17). All Naïve fish combined spent a total of 396,268 minutes at the Lewis River Hachery, which accounted for 81% of the total combined time Naïve fish spent across all locations in the study area (i.e., including both tailrace and downstream sites).

Similarly, all Non-Naïve fish combined spent a total of 580,140 minutes at the Lewis River Hachery, which accounted for 55% of the total combined time Non-Naïve fish spent across all locations in the study area (i.e., including both tailrace and downstream sites).

Non-Naïve fish also spent a large amount of time at the site downstream from their release locaiton, the Boat Launch Downtream site (274,752 or ~ 191 days; Figure 17), which accounted for 26% of the total time Non-Naïve fish spent across all locations in the study area (i.e., including both tailrace and downstream sites) and was 6 times greater than the amount of time spent in the tailrace (Non-Naïve fish spent a total of 89,714 minutes or ~ 62 days in the tailrace).

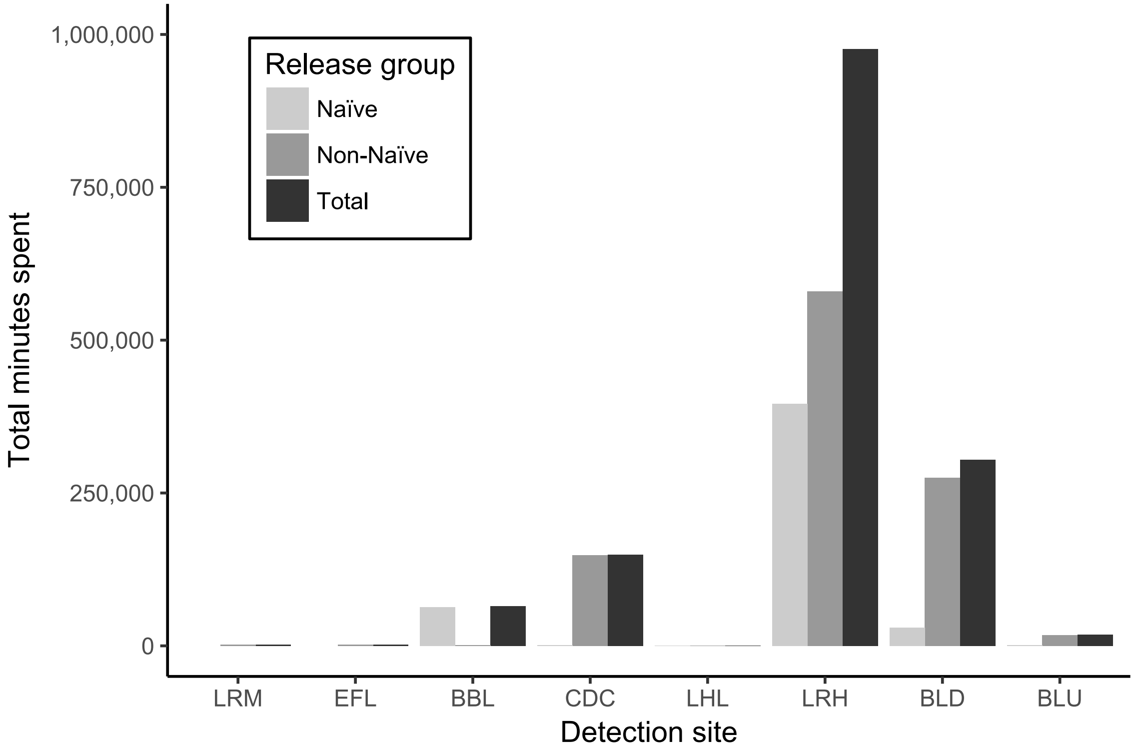

Figure 17. Total time spent by Coho salmon in each downriver site. Data are separated by release group. The Naïve release group had lower sample sizes than the Non-Naïve release group, therefore, direct comparisons of total time spent at each site between release groups is not appropriate. *Caveat: these data are not scaled based on the detection ranges of each site*. Abbreviations are given for sites as follows: LRM (Lewis River Mouth); EFL (East Fork Lewis); BBL (Bed & Breakfast); CDC (Cedar Creek); LRL (Lewis Hatchery Ladder); LRH (Lewis River Hatchery); BLD (Boat Launch Downstream); and BLU (Boat Launch Upstream).

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

The median tailrace residence time for all Coho salmon (i.e., Naïve and Non-Naïve fish combined) in the Merwin Dam tailrace was 3.5 hours (range = 1.2 minutes – 1,077 hours) (Table 8). The lower end of this range represents a fish that were only detected for a short amount of time in the tailrace before leaving, and the upper end of this range may represent total time spent during multiple trips through the tailrace. Both Naïve and Non-Naïve fish had median tailrace residence times < 24 hours (Table 8), and thus, achieved the performance standard of a median tailrace residence time of < 24 hours.

Only one Non-Naïve Coho salmon (approximately 6% of the 17 fish that passed) exhibited tailrace residence time greater than 168 hours (Table 8), which is greater than the performance standard of < 5% of fish taking longer than 168 hours to pass the tailrace.

We caution interpretations for the Naïve fish release group because only two Naïve fish entered the tailrace and only one of those was successfully captured.

A summary table of median tailrace residence times for all species and study years examined is available in Appendix A-4.

Table 8. Achieved performance standard compliance metrics for safe, timely, and effective passage of Coho salmon at Merwin Dam in 2018. Numbers of fish that entered the tailrace are presented (*M*) for each group. Metrics are also presented separately for Naïve and Non-Naïve fish.

Study Year	Species/Release Group	*M*	Median Tailrace Residence (range)	Percentage of Fish with Tailrace Residence Time > 168 hrs
2018	Coho salmon	25	3.5 hrs (0.02-1,077 hrs)	6%
	Naïve	*2*	*0.6 hrs (0.02-1.2 hrs)*	*0%*
	Non-Naïve	*23*	*3.6 hrs (0.03-1,077 hrs)*	*6%*

Additionally, the following results regarding tailrace residence times were apparent from evaluation of the detection data:

- Fourteen Coho salmon with detections in the tailrace were captured successfully.
    - These fish exhibited a median tailrace residence time of 3 hours (range = 0.4 – 1,077 hours), with one (6%) exhibiting a tailrace residence time >168 hours (Figure 18).
- Nine Coho salmon detected in the tailrace were never captured.
    - These fish exhibited a median tailrace residence time of 4 hours (range = 0.02 – 105 hrs) (Figure 18).

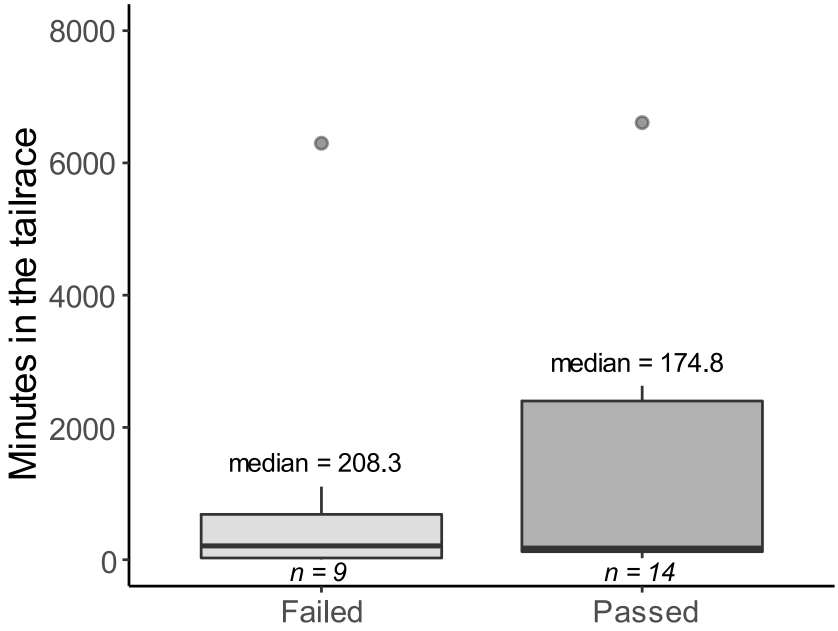

Figure 18. Boxplot showing the number of minutes in the tailrace for fish that were collected (Passed) and not collected (Failed) at the Merwin Fish Collection Facility. A single outlier was removed for a fish that Passed with a tailrace residence time of 64,621 minutes. Fish that experienced tag shed or tag failure prior to being captured are not included in this figure.

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 facilitate comparisons with previous reports and ease of interpretation, we present Objective 5 results separately for Non-Naïve fish, which are comparable to results from previous studies, and for Naïve fish.

Non-Naïve fish

Sixty-two of the 63 tagged Non-Naïve fish were detected somewhere in the study area, and thus had radio detection data available to describe movements downstream of the final Trap receiver. The following inferences can be made on the movements of these 62 fish with detection data available, but it should be noted that the numbers presented below do not account for tag sheds (e.g., we cannot determine behaviors of re-captured fish that shed their tags) and, therefore, do not correspond to those presented in Table 4 above. Also, the groups below represent intersecting (not mutually exclusive) sets, and thus do not sum to 62.

Of the 62 Non-Naïve fish detected somewhere in the study area:

- 21 fish (34%) were detected somewhere in the tailrace. Of these 21 fish detected somewhere in the tailrace,
    - 11 fish (52%) returned to downriver sites (i.e., below the access bridge). Of these 11 fish,
        - Four of 11 (36%) were eventually successfully captured at the Merwin Fish Collection Facility and
        - Two of 11 (18%) were eventually captured at the Lewis River Hatchery; the remaining 5 fish were never captured.
    - A total of 16 fish (76%) were detected somewhere in the trap ladder system. Of these 16 fish,
        - Eight fish (50%) returned to the tailrace after first visiting the trap, all of which made it further than the Entrance before exiting. Of these eight fish,
            - Five (63%) fish were recaptured at the Merwin Fish Collection Facility and
            - One (13%) fish was recaptured at the Lewis River Hatchery
- 36 fish (58%) were not re-captured but were detected somewhere in the study area. Of those 36 fish,
    - One fish (3%) was last detected at the furthest downstream site, the Lewis River Mouth (Table 9).
    - Four fish (11%) were last detected in tributaries to the Lewis River, the East Fork Lewis River (*n*=1) and Cedar Creek (*n*=3) (Table 9).
    - 21 (58%) were last detected at the Lewis River Hatchery site (Table 9).
    - ***Note:*** *The fate of fish that failed to be trapped cannot be confirmed. For example, fish last detected at the Boat Launch Downstream site could have died somewhere in the system between this site and downstream sites or could have experienced tag failure or tag regurgitation following detection at this site.*

Table 9. Last known location for the 36 Non-Naïve fish that were not re-captured but were detected somewhere in the telemetry array.

Site of Last Detection	n
Lewis River Mouth	1
East Fork Lewis	1
Bed & Breakfast	6
Cedar Creek	3
Lewis River Hatchery	21
Boat Launch Downstream	4
Total	**36**

Naïve fish

All of the 15 tagged Naïve fish were detected somewhere in the study area, and thus had radio detection data available to describe movements downstream of the final Trap receiver. The following results were apparent regarding the movements of these 15 fish with detection data available, but it should be noted that the numbers presented below do not account for tag sheds (e.g., we cannot determine behaviors of re-captured fish that shed their tags) and, therefore, do not correspond to those presented in Table 4 above. Also, the groups below represent intersecting (not mutually exclusive) sets, and thus do not sum to 15.

Of the 15 Naïve fish detected somewhere in the study area:

- Two fish (13%) were detected somewhere in the tailrace. Of these two fish detected somewhere in the tailrace,
    - One fish (50%) returned to downriver sites (i.e., below the access bridge) and was never recaptured.
    - One fish (50%) was detected entering the trap ladder system and was recaptured at the Merwin Fish Collection Facility without ever exiting the trap.
- Nine fish (60%) were not re-captured but were detected somewhere in the study area (last known detection location for these nine fish is presented in Table 10 below).

Table 10. Last known location for the nine Naïve fish that were not re-captured but were detected somewhere in the telemetry array.

Site of Last Detection	n
Lewis River Mouth	1
East Fork Lewis	1
Bed & Breakfast	3
Lewis River Hatchery	3
Boat Launch Downstream	1
Total	**9**

Objective 6: Determine the condition of Coho salmon that are captured by the trap, as a function of individual fish energetic state, and rates of descaling, injury, and reflex impairment.

Condition of Coho salmon prior to release was evaluated by measuring muscle lipid content (i.e., energetic state) of fish and assessing reflex impairment using RAMP protocol (see Methods for additional details on measuring energetic state and RAMP).

Fish energetic state

The percent muscle lipid content of fish used in the study ranged from 0.9 – 7.1 % (mean ± SD = 2.4 ± 1.7 %; n = 78). There was not a significant relationship between tagging date and muscle lipid content of fish using linear regression (df = 76; p = 0.07), and there appeared to be opposite relationships between muscle lipid content and tagging date for Naïve and Non-Naïve fish (Figure 19). Results from GLMs comparing muscle lipid content between release groups showed Naïve fish exhibited significantly higher measured muscle lipid content than Non-Naïve fish (df = 76, p = 0.004; Figure 19), even after excluding Non-Naïve fish tagged before October 1st (df = 61, p = 0.01) to create comparable tagging date ranges between Naïve and Non-Naïve fish.

NOR fish exhibited significantly higher muscle lipid content compared to HOR fish (df = 76; p = 0.02; Figure 19). However, excluding NOR fish did not change significance of relationships presented above for muscle lipid content and release date and for comparisons of muscle lipid content between Naïve and Non-Naïve fish.

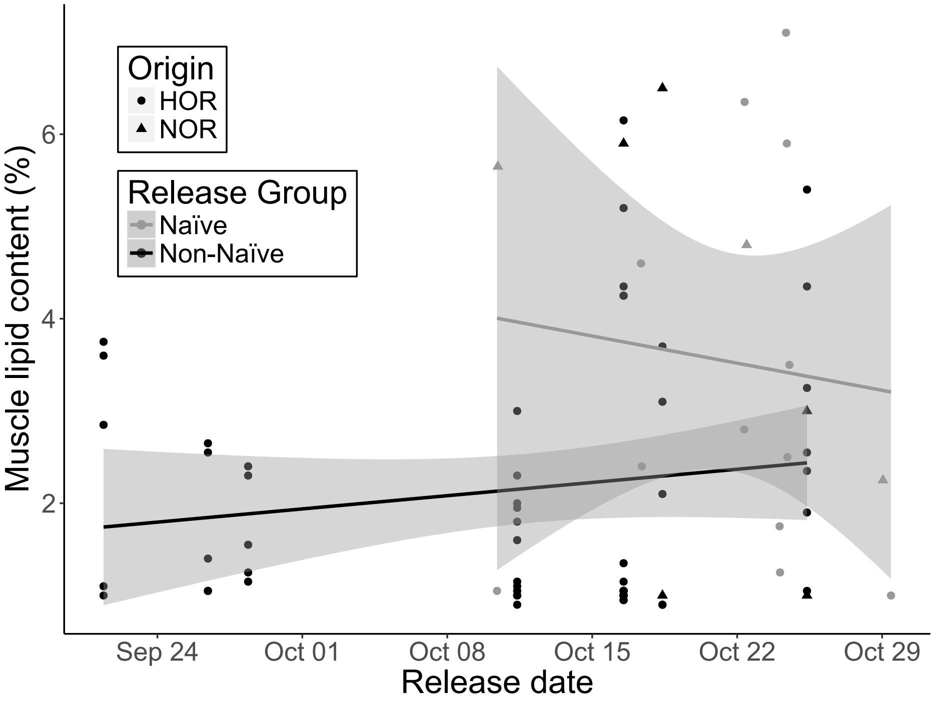

Figure 19. Muscle lipid content of individual Coho salmon by release date. Shading and symbols indicate individual fish release group (Naïve = grey; Non-Naïve = black) and fish origin (HOR = circles; NOR = triangles), respectively. Lines are based on linear regression and shaded areas around lines represent 95% confidence intervals in the fit.

We compared muscle lipid content among Non-Naïve fish with differing re-capture fates after release, including fish that were: a) not collected; b) re-captured at the Merwin Fish Collection Facility; and c) re-captured at the Lewis River Hatchery. Results from these comparisons indicated Non-Naïve fish re-captured at the Merwin Fish Collection Facility had significantly higher muscle lipid content compared to fish that were not collected (Wilcoxon rank sum test, *W* = 171.5, p = 0.021) (Figure 20). Muscle lipid content did not differ between Non-Naïve fish re-captured at the Merwin Fish Collection Facility and those re-captured at the Lewis River Hatchery, nor between Non-Naïve fish re-captured at the Lewis River Hatchery and those not collected (Figure 20). On average, Non-Naïve fish re-captured at the Merwin Fish Collection Facility had over two times greater muscle lipid content compared to fish that were not collected.

Statistical comparisons were not made between Naïve fish re-captured at the Merwin Fish Collection Facility and those not collected or those re-captured at the Lewis River Hatchery due to low sample sizes of Naïve fish re-captured at the Merwin Fish Collection Facility (*n*=1). There were no significant differences between Naïve fish re-captured at the hatchery compared to those not collected (Figure 20).

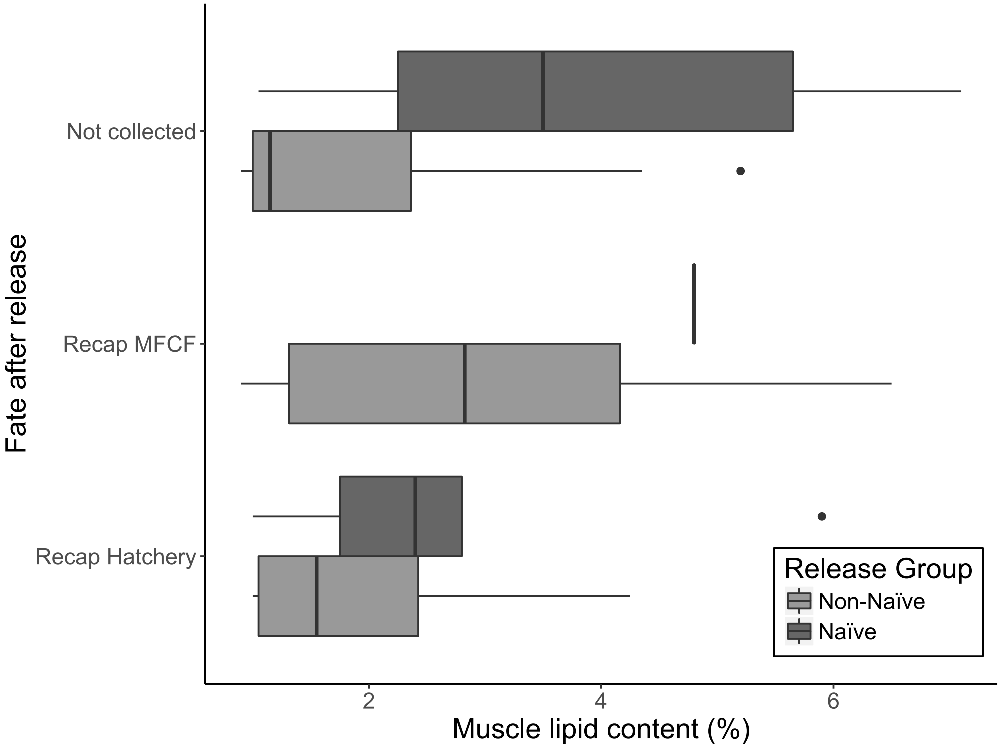

Figure 20. Box and whisker plot of the muscle lipid content of Non-Naïve and Naïve fish that were either: not collected; re-captured at the Merwin Fish Collection Facility (Recap MFCF); or re-captured at the Lewis River Hatchery (recap Hatchery) after release.

Reflex impairment

Impairment of five different reflexes was assessed for 78 fish before they were released. Of these 78 fish:

- 72 (92%) had zero impaired reflexes out of the five reflexes assessed.
- Six (8%) fish had one or more reflexes impaired; five of these fish had one reflex impaired and one fish had two reflexes impaired.
- Five out of the six fish (83%) with one or more reflex impaired were never re-captured.

Low variability of reflex impairments among fish limited the ability to statistically test for differences in reflex impairment between fish that were trapped versus not trapped after release.

OTHER

Only re-captured radio tagged fish were included in the injury assessment, because including maiden captured fish in injury assessments would be problematic, as, prior to being trapped, fish have traveled long distances and are subject to other sources of injury that cannot be separated from those caused by trapping operations. Only healthy Coho free of injury were tagged in the study. Once a radio tagged fish was re-captured, it was then inspected for injury and any found injuries were assumed to be caused by trapping effects.

No injuries or mortalities were observed on any of the fish that were recaptured at Merwin Fish Trap. Two mortalities were observed at Lewis River Hatchery, however one of those mortalities was due to intentional dispatch by hatchery staff as it was mistaken for a fish destined for a food bank. It was therefore determined that there was an observed injury rate of 0%, and a transport survival rate of 93.4% for Coho in 2018.

DISCUSSION

This report focuses on Coho salmon collected and tracked during fall 2018, the third year of reporting Coho salmon movements and passage metrics at Merwin Dam. Of note, this third study year for Coho salmon examined movements of two release groups:

- Trap Non-Naïve - Fish captured at the Merwin Fish Collection Facility and subsequently released downstream. This group is most similar to groups of Coho salmon collected in previous study years (see Drenner et al. 2018b).
- Trap Naïve - Fish captured, tagged and released downstream from Merwin Dam. This group presumably had no prior encounter with the trap.

This was the first Coho salmon study year to include a trap Naïve release group of fish; all previous Coho salmon study years used fish collected from the trap (i.e., Non-Naïve) to assess passage efficiency as Merwin Dam. A trap Naïve release group was also included in the 2018 study assessing passage efficiency of winter Steelhead at Merwin Dam, the results from which are available in a separate report (Drenner et al. 2018c)

In 2018, a total of 78 Coho salmon were tagged, including 63 Non-Naïve fish and 15 Naïve fish.

Of all 78 fish:

- 77 (99%) were detected at least once somewhere within the detection array;
- 25 (32%) entered the tailrace of Merwin Dam (M);
- 20 entered the trap (C), resulting in a raw P_{EE} $(\frac{C}{M})$ of 73%; and
- 17 were successfully captured (T), resulting in a raw ATE_{test} $(\frac{T}{M})$ of 68%.
- The Bayesian posterior estimate of ATE_{test} for all fish was 67% (95% HDI = 48-83%).

Of the 63 Non-Naïve fish:

- 62 (98%) were detected at least once somewhere within the detection array;
- 23 (37%) entered the tailrace of Merwin Dam (M);
- 19 entered the trap (C), resulting in a raw P_{EE} $(\frac{C}{M})$ of 75%; and
- 16 were successfully captured (T), resulting in a raw ATE_{test} $(\frac{T}{M})$ of 70%.
- The Bayesian posterior estimate of ATE_{test} for Non-Naïve fish was 68% (95% HDI = 49-84%).

Of the 15 tagged Naïve fish:

- 15 (100%) were detected at least once somewhere within the detection array;
- Two (13%) entered the tailrace of Merwin Dam (M);
- One entered the trap (C), resulting in a raw P_{EE} $(\frac{C}{M})$ of 50%; and
- One was successfully captured (T), resulting in a raw ATE_{test} $(\frac{T}{M})$ of 50%.
- Bayesian posterior estimate of ATE_{test} for Naïve fish was not calculated due to low sample size of Naïve fish that entered the tailrace (n=2).

Coho salmon tagged and released in 2018 included both hatchery origin (HOR, n=70) and natural origin (NOR; n=8) Coho salmon. Importantly, HOR Coho salmon originate from the Lewis River Hatchery located ~ 6 km downstream of Merwin Dam on the NF Lewis River, and thus, it is expected that some proportion of HOR Coho salmon would return to the Lewis River Hatchery. Evaluation of *ATE* at Merwin Dam is intended to apply to fish exhibiting volitional passage at Merwin Dam. It could be presumed that HOR Coho salmon that returned the Lewis River Hatchery were not exhibiting volitional dam passage behavior, and thus should not be included in estimates of *ATE* at Merwin Dam. The original intent was to tag more NOR fish, but there were low numbers of NOR fish available to tag, and therefore, HOR fish were used as surrogates.

To account for HOR Coho salmon re-captured the Lewis River Hatchery, a second measure of trap efficiency for Merwin Dam was created, $adjusted\text{-}ATE_{test}$, which excluded any fish recaptured at the Lewis River Hatchery that also entered the Merwin Dam tailrace from the total number of fish that entered the tailrace. The following insights relate to fish re-captured at the Lewis River Hatchery and calculation of $adjusted\text{-}ATE_{test}$:

- Out of 78 released fish, 16 were re-captured at the Lewis River Hatchery, two of which also entered the Merwin Dam tailrace prior to being re-captured downstream at Lewis River Hatchery.
- Excluding these two fish from the total number of fish that entered the tailrace (e.g., M - 2) resulted in an $adjusted\text{-}ATE_{test}$ of 74%.
- The Bayesian posterior estimate of $adjusted\text{-}ATE_{test}$ for Non-Naïve fish was 72% (95% HDI = 53-87%).

Whether considering ATE_{test} for either all fish together (i.e., Naïve and Non-Naïve fish combined), a subset of Non-Naïve fish, or the $adjusted\text{-}ATE_{test}$ values for these groups, all estimates of *ATE* were statistically credibly below performance standards. Moreover, there was an infinitesimal posterior probability that that the true *ATE* of the parent population of Coho salmon met the 98% performance standard for fish passage. Of note, when considering Naïve fish only, raw ATE_{test} was 50%, which is 20 percentage points lower than ATE_{test} for Non-Naïve fish. However, only two Naïve fish entered the tailrace, and thus statistical comparisons using Naïve fish were inappropriate and we caution drawing inferences about core passage metrics using Naïve Coho salmon in 2018. Overall, our results showed it was not credible that the parent population of Coho salmon in the NF Lewis River truly exhibited $ATE \geq ATE_{target}$ in 2018.

Although *ATE* performance standards were not met for Coho salmon in 2018, ATE_{test} moderately improved (by five percentage points) compared to those for Coho salmon in 2017 and substantially improved (by 59 percentage points) compared to those for Coho salmon in 2015 (although significance or credibility of this difference was not evaluated). However, we caution that these simplified comparisons of Coho salmon ATE_{test} between years may not be appropriate due to differences in samples sizes, fish origin (i.e., hatchery versus natural origin), and environmental conditions between study years. For example, HOR fish were used in 2015, NOR fish were used in 2017, and both HOR and NOR fish were used in 2018 (although only eight NOR fish were included in 2018). As described above, HOR fish originate from the Lewis River Hatchery. In comparison, NOR fish could originate from a number of different locations including above Merwin Dam, the NF Lewis River, tributaries of the NF Lewis River, or they could be strays from a different watershed. Fish that originate from different locations are expected to differ biologically and are not expected to return to the same location with equal probabilities, and thus, should not be used for comparing behavioral metrics.

Environmental factors could also contribute to observed differences in ATE_{test} between years. For example, NF Lewis River flow (hereafter 'flow') differed among study years, being highest in 2015 (mean ± sd = 6,361 ± 7,355 cfs), intermediate in 2017 (mean ± sd = 6,048 ± 3,770 cfs), and lowest in 2018 (mean ± sd = 3,574 ± 2,377 cfs). Notably, the year with the highest flow, 2015, had the lowest ATE_{test}, and the year with the lowest flow, 2018, had the highest ATE_{test}, suggesting an inverse relationship between flow and ATE_{test}. Similar relationships between flow and ATE_{test} have also been observed with winter Steelhead in the Lewis River (see Drenner et al. 2018c). Accounting for interannual environmental variation would help resolve differences in passage metrics observed for Coho salmon between years.

Although *ATE* performance standards were not met for Coho salmon, tailrace residence time performance standards were partially met. Median tailrace residence time for Non-Naïve fish (including both re-captured and not re-captured fish) in 2018 was 3.6 hours, which is less than the regulatory standard of 24 hours. However, 6% of Coho salmon in 2018 took longer than 168 hours to pass, which is slightly higher than the regulatory standard of 5%, but this was a result of a single fish that took exceedingly long to pass. Overall, the performance standard for median tailrace residence time of less than 24 hours has been met for Coho salmon in all three study years.

Also consistent with findings in previous study years, during the 2018 study year, Coho salmon appeared to locate and enter the trap at a higher rate (*PEE* = 73%) than the rate at which they were captured (ATE_{test} = 68%). This observation is reflected by a trap ineffectiveness (*Ti*) of 15% for 2018, which was lower than values reported in 2015 (61%). Reduction in *Ti* for 2018 compared to 2015 was likely the result of a fyke that was installed within the trap ladder prior to the 2017 tagging study and corresponds to findings presented in all study year since the fyke was installed (see Drenner et al. 2017; 2018a; 2018b; 2018c). Despite improvement in trap retention after installation of the fyke, in 2018, *Ti* was higher than 2017 (10%), and 50% of fish that entered the trap in 2018 exited compared to 39% in 2017. Differences in *Ti* between years after the fyke was installed could be related to differences in flow conditions in the trap ladder between years. For example, flow was lower and the number of trap exit events was greater in 2018 compared to 2017 suggesting a positive relationship between flow and trap retention (i.e., as flow increases, more fish are retained within the trap as the number of exit events from the trap decreases). This observed relationship is consistent with findings for winter Steelhead in spring 2018 (Drenner et al. 2018c).

Based on observed relationships between flow, ATE_{test}, and *Ti* among study years and across study species, we propose the following hypotheses:

a) When flow is high, as was the case in 2015, fish cannot or otherwise do not locate the tailrace/trap, e.g., because they are holding in the river to avoid high flows or because they are unable to locate attraction flows being overwhelmed by high flows.

b) When flow is moderate, as was the case in 2017, fish locate the trap more effectively than when flows are higher, possibly due to reduced station holding or increased ability to locate attraction flows. Additionally, when flow is moderate, more fish are retained within the trap, possibly because tailrace flows back up into the trap and mask directional cues that fish could otherwise exploit to locate and exit the trap through the fyke.

c) When flow is low, as was the case in 2018, fish locate the trap more effectively than at higher flows, possibly for the same reasons described above during moderate flows, but trap retention decreases, possibly because during these conditions tailrace water does not back up into the trap and therefore higher exit flows exist in the trap ladder that provide a directional cue for fish to locate and exit the trap through the fyke.

These hypotheses are based on observations across study years, and statistical modeling would be needed to better understand the relationships between environmental conditions in the NF Lewis River and passage metrics at Merwin Dam.

Under the hypothetical scenario in which trap ineffectiveness was reduced to zero (i.e., all fish that entered the trap were captured), the proportion of fish that entered the trap from the tailrace (*PEE*) would still remain lower than the ATE_{target} of 98% (this is true for all study years and species examined except Naïve winter Steelhead in 2018, which had 100% *PEE* and ATE_{test}). Thus, attraction, rather than retention, appears to be the primary factor limiting Coho salmon passage in 2018. Additional evidence to support this include:

- Results from the network analysis in 2018 indicated there was no clear pathway Coho salmon took to locate the trap after entering the tailrace.
- Coho salmon that entered the tailrace did not show a preference for either the north shore or south shore, despite attraction flows meant to guide fish to the trap entrance enter the tailrace on the south shore.
- Coho salmon milled along both the north and south shores of the tailrace, once again indicating fish were not strongly attracted to the trap entrance on the south side of the tailrace.

The above evidence for Coho salmon not being attracted to the trap entrance once they enter the tailrace is consistent with previous study year findings for Coho salmon. In addition to Coho salmon not being strongly attracted to the trap entrance from inside the tailrace, there is also evidence that Coho salmon are not generally attracted to Merwin Dam including:

- Only 37% (n=23) of tagged and released Non-Naïve Coho salmon reached the tailrace, despite being released less than one kilometer downstream of the tailrace.
- Only 13% (n=2) of tagged and released Naïve Coho salmon reached the tailrace.
- In contrast to the numbers of fish that reached the tailrace, the site where the most fish were detected was the Lewis River Hatchery (58 fish detected at this site or 74% of total released)
- Fish also spent the most time (>50% of total time) at the Lewis River Hatchery site.
- Sixteen fish (21% of total released) were re-captured at the Lewis River Hatchery site, which is approximately the same proportion of total released fish that were captured at the Merwin Fish Collection Facility (22%).

- Nine fish were detected in two tributaries of the NF Lewis River, Cedar Creek and the East Fork Lewis River, which suggest straying behaviors. Five of these nine fish were last detected in the tributaries indicating they may have been strays.
- Five fish were detected at the Lewis River Mouth site, two of which were last detected at this site and therefore may have exited the system.

It is apparent from the evidence above that Coho salmon are not generally attracted to Merwin Dam and the Merwin Dam fish trap. Interestingly, all Non-Naïve fish that were re-captured at the Merwin Fish Collection Facility (n=16) were never detected at sites further downstream than the Boat Launch where these fish are released after tagging. This indicates that at least these fish were highly attracted to Merwin Dam. Nonetheless, it remains that the majority of Coho salmon (including Non-Naïve fish) were not strongly attracted to Merwin Dam, and there are a variety of factors that could contribute to low attraction, which are described below:

- Environmental factors, such as NF Lewis River flow. For example, when total NF Lewis River flow is high, fish might choose to hold in areas to avoid swimming against energetically challenging flows or high flows might mask attraction flows.
- The background biological condition (e.g., physiological, energetic) of individual fish. In 2018, Non-Naïve Coho salmon with lower energy reserves were less likely to be re-captured at the Merwin Fish Collection Facility compared to fish with higher energy reserves. This finding is consistent with finding presented for winter Steelhead (Drenner et al. 2018c). Fish with lower energy reserves may be more reproductively advanced (i.e., they allocated more energy into gamete development) than fish with higher energy reserves, and therefore less likely to continue migration.
- Release location (Naïve versus Non-Naïve fish). In this study, Coho salmon released further downstream from Merwin Dam (Naïve fish) were less successful reaching the dam following release compared to fish released further upstream and closer to Merwin Dam (Non-Naïve fish). This is in direct contrast to result comparing Naïve and Non-Naïve winter Steelhead that showed Naïve fish performed better reaching the tailrace and were re-captured at higher rates than Non-Naïve fish. Future studies should consider having a common release location for Naïve and Non-Naïve fish to better understand the effects of release location versus trap Naivete.
- Population origin (e.g. NOR vs. HOR). This study included 70 HOR fish and only eight NOR fish. Although eight NOR fish is not enough to draw large conclusions about the differences between NOR and HOR fish, among the eight NOR fish:
  - four (50%) entered the tailrace, which is greater than the proportion of HOR fish that entered the tailrace (30%); and
  - three were recaptured, which would result in an ATE_{test} of 75% compared to an ATE_{test} of 67% for HOR fish only.

Indeed, multiple factors could be influencing evaluations of Coho salmon behavior in the NF Lewis River, and our study cannot separate the effects of these factors. It bears mentioning again, that most fish used in this study originate from the Lewis River Hatchery (i.e., they are HOR fish), and it should be expected that HOR Coho salmon would be attracted and return to the Lewis River Hatchery at high rates because Coho salmon have high degree of homesite fidelity and low straying rates (Westley et al. 2013; Keefer and Caudill 2014). Moreover, because HOR Coho salmon are expected to return to the Lewis River Hatchery, any HOR Coho salmon attempting to pass Merwin Dam could be considered displaying straying behaviors and should not be expected to have strong attraction to the Merwin Dam fish trap.

In contrast to HOR Coho salmon, blank wire tagged (BWT) winter Steelhead originate from Merwin Hatchery, the source of attraction flows discharged from the Merwin fish trap, and thus, are expected to be attracted to the fish trap. Evidence from the past four years evaluating fish passage at Merwin Dam has consistently shown BWT winter Steelhead have higher passage metrics (P_{EE}, ATE_{test}) and attraction to the fish trap at Merwin Dam compared to Coho salmon. We conclude that the use of HOR Coho salmon for evaluating performance standards for fish passage at Merwin Dam is likely inappropriate, and a more representative group of fish for evaluating fish passage at Merwin Dam is BWT winter Steelhead comprising primarily trap-naïve fish. In the future, NOR Coho salmon could provide a better study group for evaluating Coho salmon passage at Merwin Dam. However, as described above, NOR Coho salmon could originate from a number of different locations upstream and downstream of Merwin Dam, and it is not possible to differentiate between populations of Coho Salmon in the Lewis River because they are not genetically distinct. It could be assumed that any NOR Coho salmon that reach the tailrace at Merwin Dam are exhibiting volitional passage, and hence, could be used to estimate fish passage at Merwin Dam.

CONCLUSIONS

In 2018, raw estimated adult trap efficiency (ATE_{test}) of the Merwin Dam Fish Trap Facility for all tagged Coho salmon was 68% (BCI 95% CI = 48-83%), which is credibly below the performance standard of 98%.

Comparisons between Naïve and Non-Naïve Coho salmon was limited in 2018 due to small sample size (n=2) of Naïve fish that returned to Merwin Dam tailrace.

The Merwin Dam Fish Trap Facility did achieve the performance standards for median tailrace residence time of less than or equal to 24 hours (median = 3.5 hours for Coho salmon in 2018) but marginally exceeded the performance standard for less than or equal to 5% of fish taking longer than 168 hours to pass (6% of fish took longer than 168 hours to pass for Coho salmon in 2018).

Estimated raw ATE_{test} and raw P_{EE} in 2018 for Coho salmon was the highest across all three study years for Coho salmon, but only slightly higher than in 2017.

Greater trap inefficiency (T_i) in 2018 versus 2017 is the result of fish exiting the trap through a fyke installed in 2017, which could be related to flows in the trap ladder, but the fyke has reduced the number of exits compared to before it was installed.

Coho salmon were not strongly attracted to the tailrace and trap in 2018 as evidenced by the following: low ATE_{test} and P_{EE}; fish showed no preference for the side of the tailrace where the trap entrance is located compared to the opposite side of the tailrace from where the trap entrance is located; low proportion of fish reaching the tailrace following release; and fish were detected in tributaries of the NF Lewis River.

In contrast, Coho salmon showed attraction to the Lewis River Hatchery site, which had the most fish detected and was where fish spent the largest amount of time. In addition, approximately the same numbers of fish were re-captured at the Lewis River Hatchery compared to the Merwin Fish Collection Facility.

The lack of attraction to Merwin Dam and low *ATE* for Coho salmon could be related to: environmental conditions (e.g., river flow); fish biological condition (e.g., fish that were recaptured had higher energy reserves compared to fish that were not recaptured); release location (e.g., Naïve vs. Non-Naïve fish); and/or population origin (e.g., HOR vs. NOR fish).

HOR Coho salmon, which made up the majority (90%) of tagged fish in 2018, originate from the Lewis River Hatchery and therefore, the observed attraction of Coho salmon to the hatchery (or lack of attraction to Merwin Dam) is to be expected.

We contend that the use of HOR Coho salmon for evaluating passage at Merwin Dam is likely inappropriate. Trap naïve BWT winter Steelhead are likely a better study group for evaluating passage at Merwin Dam, but NOR Coho salmon from the upper basin could potentially be used in future studies.

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APPENDIX A: SUPPLEMENTARY INFORMATION

A-1 Radio antennas technical information

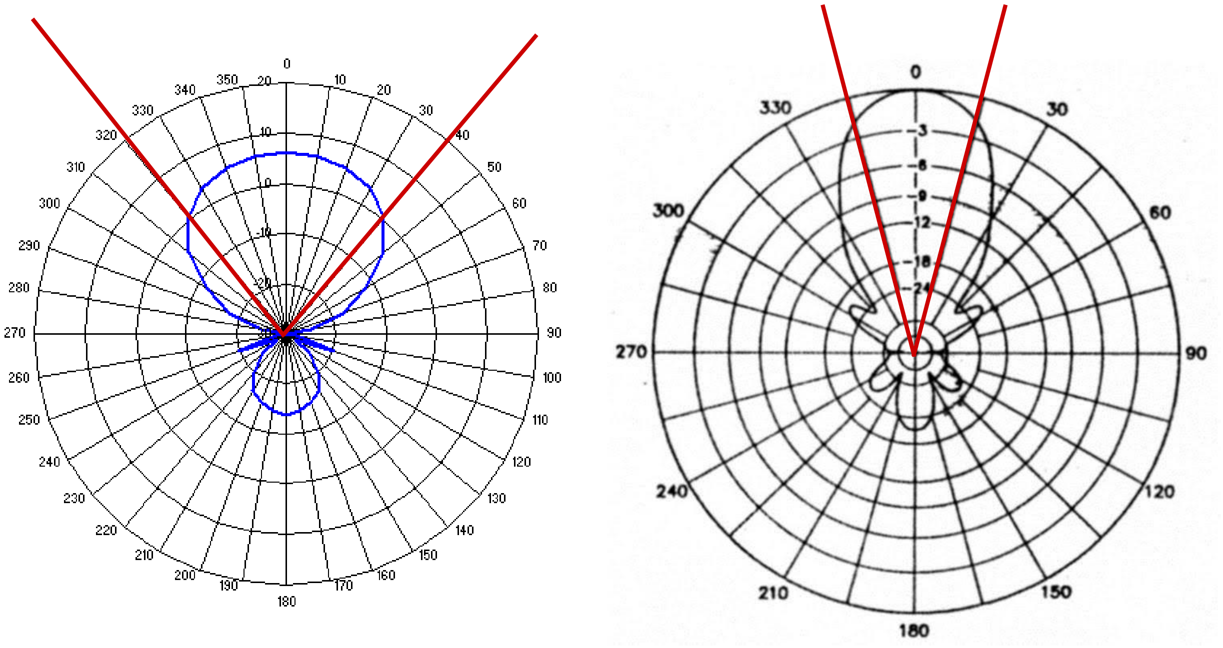
Five types of antennas were used during the 2018 Merwin *ATE* study: 3-, 6-, and 8-element aerial antennas, and underwater antennas. We describe the use and locations of these four antenna types below, with additional details provided in Table 2 above. *Three-element Yagi antennas* – Three-element antennas have a 6 dBd gain increase, the smallest dBd gain of the three Yagi-UDA© (Yagi) antennas used in the Merwin ATE. Three-element Yagi antennas were oriented in two ways, vertically and horizontally relative to the surface of the river. At the BRG site, four vertically mounted 3-element antennas were combined and amplified to detect tagged fish in the tailrace directly beneath the Merwin access bridge. At the APR site, a single vertically mounted 3-element antenna was pointed at the transition area to accurately detect fish between the adult trap and the tailrace. Three-element antennas at the PWN, PWS, SSS, and NSS sites were mounted horizontally to the tailrace.

Six-element Yagi antennas - Six-element antennas have an intermediate (7 dBd) gain increase, and were used for detecting tagged fish in the mainstem of the Lewis River, specifically at the BLU, BLD, LFH and BBL gate sites. Six-element antennas were successfully used for detecting tagged fish across the entire river channel, thus they were used as gate sites.

Eight-element Yagi antennas – Eight-element antennas have an 11.8 dBd gain increase, the largest increase of the Yagi antennas used in the Merwin ATE. These antennas were used at the NSL and SSL sites, and detected tagged fish within a narrower range than the 3- and 6-element antennas.

Underwater antennas - Underwater antennas were used to detect tagged fish in very small areas where high resolution tracking is needed, such as areas within the Merwin Dam fish passage facilities. While detection probability was important at all sites, for these underwater antennas the explicit array design tradeoff was one that valued specificity (confidence in location) over sensitivity (ability to detect every fish). The typical range of these antennas was 10-20 feet in diameter. Receiver gain settings were typically low for these sites due to the proximity of fish to the receivers in confined areas. Underwater antennas were used exclusively in the adult trap and the collection pool sites. At sites PL2, PL3, and PL4, underwater antennas were contained within ¾ inch electrical conduit tubing attached to the fishway with Hilti® concrete bolts. Underwater antenna cables at the ENT, HOP, and TRP sites were weighted down with lead weights.

The type of aerial antenna used at each site was selected based on the strengths and weaknesses of each antenna type. As discussed above, the 3-element antenna has a shorter but very wide (~80°) tag detection area, while the 8-element antenna has a longer but much narrower (~30°) tag detection area (Figure 21), and the 6-element antenna provides detection areas of intermediate distance and width. Collectively, the use of these three different antennas allowed us to optimize fish detection in different parts of the study area.



3-element antenna

8-element antenna

Figure 21. Reception radiation patterns (tag detection areas) for short-range 3-element (6.0dBd) and long-range 8-element (11.8dBd) Yagi antennas. Numbers around the perimeter of each figure represent directional degrees.

Fish detection ranges varied at receiver sites using the three different antennas depending on mounting orientation and gain settings. Individual antenna orientation and gain settings were optimized for either specificity (trap sites) or sensitivity (most other sites) in detecting tagged fish. Gain settings were adjusted based on empirical results of in-river validation of test radio tags at depths of 5 to 10 feet in the study area.

Two main factors can influence tag detections, tag depth and tag-antenna orientation, with tag depth being the most important factor influencing detections. A radio tag signal loses energy as it travels through water. Radio tags that are deeper in the water column require a longer signal path to reach aerial antennas (and shallow underwater antennas). As a result, the signal from these deeper tags is weaker when it reaches the receiver compared to tags that are shallower in the column. In addition to tag depth, the relative radial/axial orientation between tag and the 6-inch antenna influences signal strength.

Detection ranges were evaluated indirectly during setup optimization and are reported qualitatively, rather than as detection zones with defined areas. After receivers were constructed and antennas were oriented, detection ranges were evaluated for all receivers within the Merwin Dam tailrace. Range testing followed this general protocol:

- A radio tag attached by zip ties and electrical tape to a rope weighted with a cannonball was lowered into the water column from a boat.
- The boat was driven or drifted along a path or paths selected to evaluate detection range for each receiver in the tailrace.

- Receivers were simultaneously monitored for detection of the tag during deployment from the boat.
- Position of the boat and tag was relayed by handheld radio to the person monitoring receivers.
- The tag was drifted at approximately 7 ft. depth for all antenna sites, and at 7 ft. and 25 ft. depth for the Bridge site.
- If detection ranges did not match expectations associated with array design, adjustments were made to receivers.
- Protocol was repeated until detection ranges were as intended (see Figure 5 for intended detection ranges).

Following initial set-up and range testing, routine inspection of detection data was also made throughout the study to verify detection ranges remained as intended.

A-2 Data Management and Processing

Database Construction

Data from weekly 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 one or two 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 GMT time.

Raw detection records were processed and compiled into a single MS Access database. During this process, detections determined to be noise or from a tag code not included in our study were filtered out. 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 stored in separate tables 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, tags from past tracking efforts that remain within the system, 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), with following QA goals:

1) Remove consecutive detections at a single site, with the exception of the first and last detection per visit.
2) Calculate the total number of exit events that an individual made from the trap or from the tailrace regions to categorize fish movements in and around the adult trap and bridge.

To achieve these QA goals, an automated data filter was applied, which 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:
    - A sequence of four detections within 15 minutes of each other was required to be a “credible” detection. If the four consecutive detections spanned more than 15 minutes, it was not considered a credible detection.
    - At the pre-sort pond receiver (Trap), only one 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 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 while these fish were in the tailrace; requiring a strong signal, although conservative from the perspective of sensitivity, provides greater confidence that a fish had passed directly adjacent to the antenna (i.e., this approach optimizes specificity of detections at this site).

- 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.
- Fish were assumed to exit the trap when they moved from any of the trap sites inside the fish ladder (i.e., Entrance, Pool 2, Pool 4, Hopper) to any of the sites outside the trap (i.e., Approach, Bed and Breakfast, Boat Launch sites, Bridge, Lewis River Hatchery, North Shore, Powerhouse North, Powerhouse South, 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.
- Detections at the Bridge site that occur between detections at the pool, hopper, and Trap sites were discarded. These detections were determined to be faulty as there is no way for fish to move between these sites and the bridge in a rapid succession.
- 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.

Database QA Results

There were 3,170,661 detections in the raw data, and 2,846,790 retained detections after the filter was applied.

Noise detections can prevent an antenna from detecting valid transmissions from a real transmitter (tag). In this study, noise accounted for 323,871 of total detections (10%), a reasonable value considering the conditions of the study (e.g., a dam tailrace and bridge with occasional car and truck traffic). Noise levels were generally higher for receivers located at the trap than those stationed in the tailrace (Figure 22). The largest "peak" of noise detections came from the trap sites on 28 October, potentially due to more tagged fish in the system, more tagging events, or operational patterns (Figure 22). The receivers with the most noise hits were: Cedar Creek (43% of all noise detections), Bed & Breakfast (17%), and Hopper (16%).

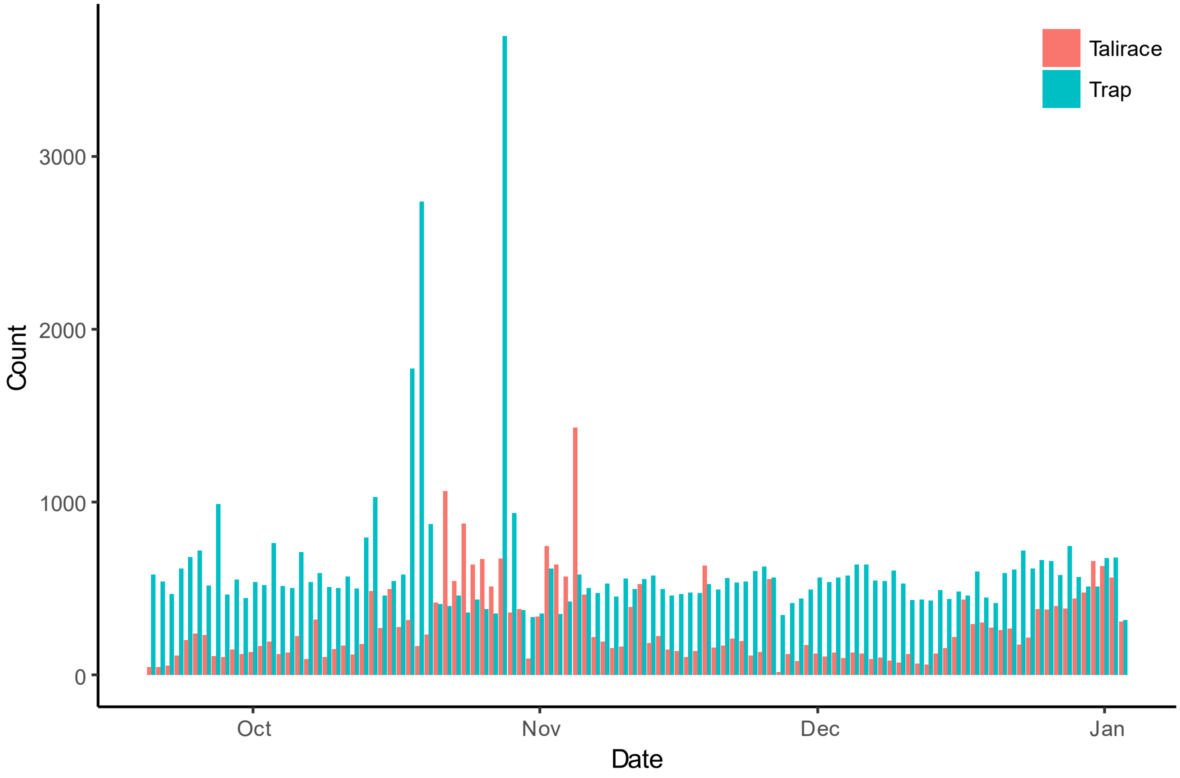


Figure 22. Total number of noise detections for tailrace (red) and trap (blue) receivers.

A-3 Individual Fish Summary Data

Table 11. Individual Coho salmon characteristics and detection data summaries from all fish tagged and released in 2018. The ‘Fish Code’ is the unique radio tag code. All radio tags were in the frequency 166.776.

Fish Code	Origin	Release Group	Sex	Fork Length (cm)	PIT ID	Release Date/Time	First Detection Location	First Detection Date/Time	Furthest Upstream Detection Location	Furthest Upstream Detection Date/Time	Last Detection Location	Last Detection Date/Time	Recaptured	Recapture Location
120	HOR	Naïve	M	69	3DD.003C011570	10/24/2018 1:12	LRH	10/28/2018 14:25	LHL	11/22/2018 16:09	LRH	11/27/2018 14:33	Y	LRH
122	HOR	Naïve	F	65	3DD.003C01158A	10/24/2018 1:41	LRH	10/31/2018 2:36	BBL	11/14/2018 6:29	BBL	11/26/2018 11:17	N	N/A
171	NOR	Naïve	F	74	3DD.003C0115B0	10/10/2018 10:36	LRH	10/16/2018 0:37	LRM	10/20/2018 10:29	LRM	10/20/2018 10:33	N	N/A
193	HOR	Naïve	M	58	3DD.003C011565	10/17/2018 8:31	LRH	10/20/2018 21:13	BBL	10/21/2018 11:12	BBL	10/21/2018 11:30	N	N/A
194	NOR	Naïve	F	72	3DD.003C011579	10/22/2018 11:02	BLD	11/30/2018 11:13	TRP	12/18/2018 15:23	TRP	12/18/2018 15:23	Y	MFCF
195	HOR	Naïve	M	67	3DD.003C011587	10/24/2018 12:34	LRH	10/28/2018 13:47	LRH	10/28/2018 13:47	LRH	12/27/2018 12:45	N	N/A
196	HOR	Naïve	M	64	3DD.003C0115BB	10/17/2018 9:26	LRH	10/20/2018 2:31	LRH	10/20/2018 2:31	LRH	10/30/2018 10:47	Y	LRH
197	HOR	Naïve	F	67	3DD.003C011564	10/10/2018 9:41	LRH	10/10/2018 10:01	LRH	10/10/2018 10:01	BLD	10/20/2018 6:49	N	N/A
198	HOR	Non-Naïve	F	62	3DD.003C011043	9/26/2018 10:36	BLD	9/26/2018 10:45	TRP	9/27/2018 0:49	TRP	9/27/2018 0:49	Y	MFCF
201	HOR	Non-Naïve	M	61	3DD.003C010FF2	9/21/2018 9:36	BLU	9/25/2018 1:27	TRP	9/25/2018 3:06	TRP	9/25/2018 3:06	Y	MFCF
202	HOR	Non-Naïve	F	67	3DD.003C011042	9/21/2018 9:36	BLD	9/21/2018 9:48	TRP	9/24/2018 0:18	TRP	9/24/2018 0:18	Y	MFCF
203	HOR	Non-Naïve	M	69	3DD.003C01100F	9/21/2018 9:36	BLD	9/21/2018 9:41	LRH	9/28/2018 2:04	LRH	9/28/2018 20:42	N	N/A
204	HOR	Non-Naïve	M	65	3DD.003C01101F	9/21/2018 9:36	BLU	10/6/2018 2:53	BRG	10/11/2018 0:05	BLD	10/24/2018 7:31	N	N/A
205	HOR	Non-Naïve	F	70	3DD.003C01103D	9/21/2018 9:36	BLD	9/21/2018 9:41	HOP	9/23/2018 14:48	LRH	10/20/2018 0:38	Y	LRH
206	HOR	Non-Naïve	M	53	3DD.003C011045	9/26/2018 10:36	BLD	9/26/2018 12:34	LRH	10/3/2018 20:46	LRH	10/4/2018 11:57	N	N/A
207	HOR	Non-Naïve	M	61	3DD.003C01101A	9/26/2018 10:36	BLU	9/26/2018 12:12	TRP	9/26/2018 16:56	TRP	9/26/2018 16:56	Y	MFCF
208	HOR	Non-Naïve	F	68	3DD.003C011049	9/26/2018 10:36	BLD	9/26/2018 15:23	APR	10/12/2018 10:46	LRH	10/12/2018 10:46	Y	LRH
209	HOR	Non-Naïve	M	69	3DD.003C01102E	9/28/2018 9:11	BLD	9/28/2018 9:16	LRM	10/5/2018 4:49	BBL	10/6/2018 8:50	N	N/A
210	HOR	Non-Naïve	M	64	3DD.003C011044	9/28/2018 9:11	BLD	9/28/2018 13:03	TRP	10/3/2018 11:31	TRP	10/3/2018 11:31	Y	MFCF
211	HOR	Non-	M	63	3DD.003C011040	9/28/2018	BLD	9/28/2018	HOP	10/6/2018	LRH	10/17/2018	N	N/A

Fish Code	Origin	Release Group	Sex	Fork Length (cm)	PIT ID	Release Date/Time	First Detection Location	First Detection Date/Time	Furthest Upstream Detection Location	Furthest Upstream Detection Date/Time	Last Detection Location	Last Detection Date/Time	Recaptured	Recapture Location
		Naïve				9:11		15:14		12:36		6:29		
212	HOR	Non-Naïve	M	57	3DD.003C011023	9/28/2018 9:11	BLD	9/28/2018 20:20	LRH	10/3/2018 22:25	LRH	10/15/2018 15:09	N	N/A
213	HOR	Non-Naïve	M	59	3DD.003C011005	9/28/2018 9:11	BLU	9/28/2018 11:20	BLU	9/28/2018 11:20	LRH	10/16/2018 9:24	Y	LRH
214	HOR	Non-Naïve	M	65	3DD.003CO11022	10/11/2018 9:02	BLU	10/11/2018 9:13	BLU	10/11/2018 9:13	BLD	10/25/2018 12:28	N	N/A
215	HOR	Non-Naïve	F	68	3DD.003CO10FFB	10/11/2018 9:02	BLD	10/11/2018 12:41	TRP	10/14/2018 3:21	TRP	10/14/2018 3:21	Y	MFCF
216	HOR	Non-Naïve	F	62	3DD.003CO1103C	10/11/2018 9:02	BLU	10/13/2018 11:53	TRP	10/13/2018 15:25	TRP	10/13/2018 15:25	Y	MFCF
217	HOR	Non-Naïve	M	77	3DD.003CO11039	10/11/2018 9:02	BLU	10/13/2018 19:04	PWN	10/14/2018 2:22	LRH	10/15/2018 20:25	N	N/A
218	HOR	Non-Naïve	M	74	3DD.003CO1103A	10/11/2018 9:02	BLD	10/11/2018 11:01	LRH	10/12/2018 21:19	LRH	10/13/2018 9:11	N	N/A
219	HOR	Non-Naïve	F	70	3DD.003CO1102B	10/11/2018 9:02	BLD	10/11/2018 9:08	TRP	10/18/2018 16:48	TRP	10/18/2018 16:48	Y	MFCF
220	HOR	Non-Naïve	M	70	3DD.003CO11035	10/11/2018 9:02	LRH	10/25/2018 0:11	LRH	10/25/2018 0:11	LRH	10/30/2018 10:10	Y	LRH
221	HOR	Non-Naïve	F	60	3DD.003CO11048	10/11/2018 9:02	BBL	10/16/2018 10:47	BBL	10/16/2018 10:47	BBL	10/16/2018 10:50	N	N/A
222	HOR	Non-Naïve	M	74	3DD.003CO11017	10/11/2018 9:02	BLD	10/11/2018 11:20	TRP	10/18/2018 14:40	TRP	10/18/2018 14:40	Y	MFCF
223	HOR	Non-Naïve	M	60	3DD.003CO11015	10/11/2018 9:02	BLD	10/11/2018 15:27	BBL	10/14/2018 12:03	BBL	10/14/2018 13:26	N	N/A
224	HOR	Non-Naïve	M	66	3DD.003CO1101C	10/11/2018 9:02	BLD	10/11/2018 9:09	BLD	10/11/2018 9:09	BLD	10/12/2018 12:00	N	N/A
225	HOR	Non-Naïve	M	67	3DD.003CO11036	10/11/2018 9:02	BLD	10/11/2018 13:28	BBL	10/17/2018 7:37	BBL	10/17/2018 7:45	N	N/A
226	HOR	Non-Naïve	M	66	3DD.003C011010	10/16/2018 12:21	BLD	10/16/2018 18:44	LRH	10/20/2018 4:48	LRH	11/13/2018 12:00	Y	LRH
227	HOR	Non-Naïve	M	65	3DD.003C011024	10/16/2018 12:21	BLD	10/16/2018 13:44	EFL	10/21/2018 1:00	BLD	10/25/2018 12:06	N	N/A
228	HOR	Non-Naïve	F	64	3DD.003C011033	10/16/2018 12:21	BLD	10/16/2018 15:18	LRM	10/22/2018 22:43	LRM	10/23/2018 7:06	N	N/A
229	HOR	Non-Naïve	F	64	3DD.003C011034	10/16/2018 12:21	LRH	10/25/2018 23:25	LRH	10/25/2018 23:25	LRH	10/29/2018 0:36	Y	LRH
230	HOR	Non-Naïve	M	67	3DD.003C011008	10/16/2018 12:21	LRH	10/18/2018 3:50	LHL	11/2/2018 22:43	LRH	11/13/2018 12:01	Y	LRH
231	HOR	Non-Naïve	F	65	3DD.003C011012	10/16/2018 12:21	BLD	10/16/2018 12:51	BBL	10/23/2018 3:35	LRH	10/24/2018 7:22	N	N/A
232	NOR	Non-Naïve	F	72	3DD.003C011006	10/16/2018 12:21	BLU	10/16/2018 15:28	TRP	10/28/2018 12:26	TRP	10/28/2018 12:26	Y	MFCF
233	HOR	Non-Naïve	F	68	3DD.003C010FEF	10/16/2018 12:21	BLD	10/16/2018 14:53	CDC	10/19/2018 21:12	CDC	11/26/2018 10:53	N	N/A

Fish Code	Origin	Release Group	Sex	Fork Length (cm)	PIT ID	Release Date/Time	First Detection Location	First Detection Date/Time	Furthest Upstream Detection Location	Furthest Upstream Detection Date/Time	Last Detection Location	Last Detection Date/Time	Recaptured	Recapture Location
234	HOR	Non-Naïve	M	78	3DD.003C010FEB	10/16/2018 12:21	BLD	10/16/2018 19:18	LRH	10/21/2018 21:50	LRH	10/24/2018 15:26	N	N/A
235	HOR	Non-Naïve	F	65	3DD.003C011031	10/16/2018 12:21	APR	10/16/2018 16:18	PL2	12/5/2018 16:38	TRP	12/5/2018 16:38	Y	MFCF
236	HOR	Non-Naïve	M	67	3DD.003C01100E	10/16/2018 12:21	BLD	10/16/2018 12:47	TRP	11/2/2018 3:23	TRP	11/2/2018 3:23	Y	MFCF
237	HOR	Non-Naïve	F	63	3DD.003C010FF3	10/16/2018 12:21	BLD	10/16/2018 14:32	LRH	10/17/2018 2:23	LRH	10/20/2018 12:27	N	N/A
238	HOR	Non-Naïve	M	63	3DD.003C011014	10/16/2018 12:21	LRH	10/28/2018 0:33	LRH	10/28/2018 0:33	LRH	10/28/2018 12:37	N	N/A
239	HOR	Non-Naïve	M	75	3DD.003C01102A	10/16/2018 12:21	BLD	10/16/2018 14:56	PL4	10/19/2018 0:11	BBL	10/25/2018 17:50	N	N/A
240	HOR	Non-Naïve	M	67	3DD.003C011001	10/16/2018 12:21	BLD	10/16/2018 15:13	LRH	10/17/2018 2:18	LRH	11/5/2018 10:48	Y	LRH
241	HOR	Non-Naïve	F	73	3DD.003C01102C	10/16/2018 12:21	BLD	10/16/2018 15:31	LRH	10/17/2018 3:31	LRH	11/5/2018 10:48	Y	LRH
242	HOR	Non-Naïve	F	76	3DD.003C010FEE	10/16/2018 12:21	BLD	10/16/2018 12:37	CDC	10/20/2018 21:45	CDC	11/26/2018 10:53	N	N/A
243	HOR	Non-Naïve	F	67	3DD.003C01101E	10/16/2018 12:21	BLD	10/16/2018 14:31	LRH	10/18/2018 23:22	LRH	10/21/2018 21:48	N	N/A
244	HOR	Non-Naïve	F	67	3DD.003C011009	10/16/2018 12:21	BLD	10/16/2018 17:17	LRM	10/21/2018 16:31	EFL	10/22/2018 18:20	N	N/A
245	HOR	Non-Naïve	F	68	3DD.003C010FF7	10/16/2018 12:21	BLD	10/16/2018 15:52	LRH	10/17/2018 20:59	LRH	10/21/2018 3:30	N	N/A
252	HOR	Naïve	F	71	3DD.003C01159E	10/24/2018 9:36	BBL	10/24/2018 22:00	BBL	10/24/2018 22:00	LRH	12/21/2018 13:35	Y	LRH
256	HOR	Naïve	F	73	3DD.003C0115B9	10/22/2018 8:38	BBL	10/25/2018 16:09	BBL	10/25/2018 16:09	BBL	11/26/2018 11:17	N	N/A
262	HOR	Non-Naïve	M	62	3DD.003C010FFF	10/18/2018 9:24	BLD	10/18/2018 11:39	TRP	10/28/2018 11:21	TRP	10/28/2018 11:21	Y	MFCF
264	HOR	Naïve	F	58	3DD.003C01158D	10/24/2018 8:38	BBL	11/1/2018 7:20	BBL	11/1/2018 7:20	LRH	12/27/2018 12:51	N	N/A
265	NOR	Non-Naïve	M	76	3DD.003BE8C513	10/18/2018 9:24	BLD	10/18/2018 17:09	CDC	10/24/2018 20:36	CDC	11/22/2018 14:23	N	N/A
268	HOR	Non-Naïve	F	63	3DD.003C01101B	10/18/2018 9:24	BLD	10/18/2018 14:35	LHL	11/20/2018 7:34	LRH	12/5/2018 13:28	Y	LRH
271	HOR	Non-Naïve	M	65	3DD.003C011004	10/18/2018 9:24	BLU	10/18/2018 9:29	BLU	10/18/2018 9:29	LRH	12/27/2018 12:48	N	N/A
274	HOR	Non-Naïve	F	73	3DD.003D278A21	10/25/2018 8:56	LRH	10/30/2018 0:27	LRH	10/30/2018 0:27	LRH	11/19/2018 0:30	N	N/A
276	HOR	Naïve	F	67	3DD.003C011569	10/29/2018 10:20	LRH	10/29/2018 12:50	LHL	11/17/2018 0:45	LRH	11/19/2018 12:12	Y	LRH
277	HOR	Non-Naïve	M	68	3DD.003D2D2AC	10/25/2018 8:56	BLD	10/25/2018 12:13	LHL	11/24/2018 2:31	LRH	11/27/2018 14:37	Y	LRH
280	HOR	Non-	F	70	3DD.003D2788EB	10/25/2018	BLD	10/25/2018	LHL	12/9/2018	LRH	12/26/2018	N	N/A

Fish Code	Origin	Release Group	Sex	Fork Length (cm)	PIT ID	Release Date/Time	First Detection Location	First Detection Date/Time	Furthest Upstream Detection Location	Furthest Upstream Detection Date/Time	Last Detection Location	Last Detection Date/Time	Recaptured	Recapture Location
		Naïve				8:56		9:04		17:29		13:39		
283	NOR	Non-Naïve	F	70	3DD.003D27B54E	10/25/2018 8:56	BLD	10/25/2018 11:05	LRH	10/25/2018 22:40	LRH	12/30/2018 13:42	N	N/A
286	HOR	Non-Naïve	M	67	3DD.003D278AC7	10/25/2018 8:56	BLD	10/25/2018 9:32	TRP	10/28/2018 12:26	TRP	10/28/2018 12:26	Y	MFCF
289	HOR	Non-Naïve	F	66	3DD.003D27CAA3	10/25/2018 8:56	BLD	10/25/2018 9:02	LRH	10/29/2018 17:47	LRH	10/30/2018 2:40	N	N/A
291	HOR	Naïve	M	72	3DD.003C0115A6	10/24/2018 10:15	BBL	10/27/2018 20:18	BBL	10/27/2018 20:18	LRH	1/2/2019 3:43	N	N/A
292	HOR	Naïve	M	73	3DD.003C011582	10/22/2018 8:08	BBL	11/1/2018 13:42	BBL	11/1/2018 13:42	LRH	11/27/2018 12:58	Y	LRH
295	HOR	Non-Naïve	F	67	3DD.003C010FF1	10/18/2018 9:24	BLD	10/19/2018 23:19	BBL	10/23/2018 8:15	BBL	10/23/2018 10:13	N	N/A
298	NOR	Non-Naïve	M	58	3DD.003C011025	10/18/2018 9:24	BLD	10/18/2018 9:39	BLD	11/19/2018 6:06	TRP	11/19/2018 6:06	Y	MFCF
301	HOR	Non-Naïve	F	65	3DD.003C01104A	10/18/2018 9:24	BLU	10/20/2018 16:38	BRG	10/20/2018 17:29	LRH	10/25/2018 6:41	N	N/A
304	HOR	Non-Naïve	M	60	3DD.003D279E68	10/25/2018 8:56	BLD	10/25/2018 9:01	LRH	10/29/2018 16:40	LRH	10/31/2018 19:04	N	N/A
307	NOR	Non-Naïve	M	63	3DD.003D2794FE	10/25/2018 8:56	BLD	10/25/2018 12:33	LRH	10/27/2018 11:06	LRH	10/31/2018 0:50	N	N/A
309	NOR	Naïve	F	68	3DD.003C011594	10/29/2018 1:00	LRH	11/22/2018 14:07	SS	11/22/2018 23:17	EFL	11/27/2018 13:13	N	N/A
310	HOR	Non-Naïve	M	58	3DD.003D27FF17	10/25/2018 8:56	BLD	10/25/2018 9:01	LRH	10/26/2018 22:39	LRH	10/28/2018 14:08	N	N/A

A-4 Tailrace Residence Time Summary Table

Table 12. Achieved performance standard compliance metrics for safe, timely, and effective passage across four study years for three study species at Merwin Dam. Sample sizes (*N*) are for total number of fish tagged. In 2018, metrics are also presented separately for Naïve and Non-Naïve fish.

Study Year	Species/Release Group	*N*	Median Tailrace Residence (range)	Percentage of Fish with Tailrace Residence Time > 168 hrs
2015	Winter Steelhead	148	49.4 hrs (0.08-1,077.4 hrs)	14%
	Spring Chinook	40	246.5 hrs (0.01-1412.4 hrs)	65%
	Coho Salmon	35	15.3 hrs(0.21-395.7 hrs)	6%
2016	Winter Steelhead	148	29.2 hrs (0.03-605 hrs)	10%
	Spring Chinook	*N/A*	*N/A*	*N/A*
	Coho salmon	*N/A*	*N/A*	*N/A*
2017	Winter Steelhead	150	11.8 hrs (0.03-403 hrs)	7%
	Spring Chinook	*N/A*	*N/A*	*N/A*
	Coho salmon	149	5.6 hrs (0.03-192 hrs)	2%
2018	Winter Steelhead	92	14.0 hrs (0.12-219 hrs)	4%
	Naïve	*19*	*6.0 hrs (0.7-90.5 hrs)*	*0%*
	Non-Naïve	*73*	*19.8 hrs (0.12-219 hrs)*	*4%*
	Coho salmon	78	3.5 hrs (0.02-1,077 hrs)	6%
	Naïve	*15*	*0.6 hrs (0.02-1.2 hrs)*	*0%*
	Non-Naïve	*63*	*3.6 hrs (0.03-1,077 hrs)*	*6%*

APPENDIX D

SPAWN TIMING, DISTRIBUTION AND ABUNDANCE OF TRANSPORTED FISHES – 2018 REPORT

Meridian
Environmental, Inc.

Environmental Sciences
Regulatory Planning
Project Management

Memorandum

To: Erik Lesko, PacifiCorp, Chris Karchesky, PacifiCorp

From: Jason Shappart, Fisheries Scientist

Date: February 21, 2019

Re: NF Lewis River upstream of Swift Dam – 2018 Spawning Survey Results

Introduction

Coho and spring Chinook salmon spawning surveys were conducted from September 1 through December 31, 2018 by Meridian Environmental, Inc. (through contract with PacifiCorp). Per Objective 15 of the Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2017), surveys were conducted to provide the basis for estimating the spawner abundance, timing, and distribution of transported adult anadromous fish in the North Fork Lewis River upstream of Swift Dam.

The original spawning survey sample design was developed in 2012. All stream habitat potentially accessible to transported anadromous fish upstream of Swift Dam was divided into discrete approximately 0.3-mile-long reaches, and 33% of all available reaches were drawn into three randomly-stratified yearly survey panels. The year-1 panel of survey reaches was visited for the first time in 2012, year-2 panel in 2013, and year-3 panel in 2014. In 2018, the year-1 panel received its third visit since first being surveyed in 2012 and resurveyed in 2015.

This memorandum summarizes salmon spawning survey results for the year-1 reach survey panel conducted from September 1 to December 31, 2018. The 2012 and 2015 results are also discussed, where possible, to illustrate potential changes in transported anadromous fish spawn timing, distribution and abundance over time. However comparison with prior year survey results (of the same year-1 reach panel) is limited due to low abundance of transported adult coho in 2012 and poor survey conditions (due to persistent high flows) during 2015. Chinook were not transported upstream in 2012 and 2015 due to low abundance. Chinook were first transported upstream in substantial numbers in 2017 and the overall spawning distribution pattern observed is compared to the pattern observed in 2018. The overall proportion of female coho determined to have spawned over the last five years is also discussed.

Survey Conditions

The USGS North Fork Lewis River above Muddy River gage[1] approximates general flow patterns relative to median conditions throughout the basin during the survey season (Figure 1). Daily flows were generally well below median base flow levels from September through late November (Figure 1). During this time period, daily average flows were

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[1] https://waterdata.usgs.gov/nwis/uv?site_no=14216000

generally between the 90 to 95% daily exceedence flows based on the period of record. Or in other words, there is about a 5 to 10% chance of such low flows occurring each year. Small tributary streams within the year-1 survey panel were either totally dry or too low to allow upstream migration of salmon spawners from September through late-October, including all reservoir tributaries (S10, S15, S20, Range, and Drift creeks) and many of the small tributaries throughout the upper basin (Pepper, Chickoon, P1, P3, P7, and Cussed Hollow creeks).

Flows over about 1,000 cfs (Lewis River above Muddy River gage) are considered unsafe for conducting float surveys on the upper NF Lewis River mainstem and visibility is also generally greatly reduced. However, flows were generally below 1,000 cfs during the survey season, which allowed for several float surveys to be conducted. Snow and closed gates limited upper Muddy River and Pine Creek watershed surveys after the first week in November. The low level of Swift Reservoir limited launching a boat to conduct reservoir tributary surveys during November and December. High flows during the 2nd half of December rendered most streams unsurveyable for the remainder of the survey season.

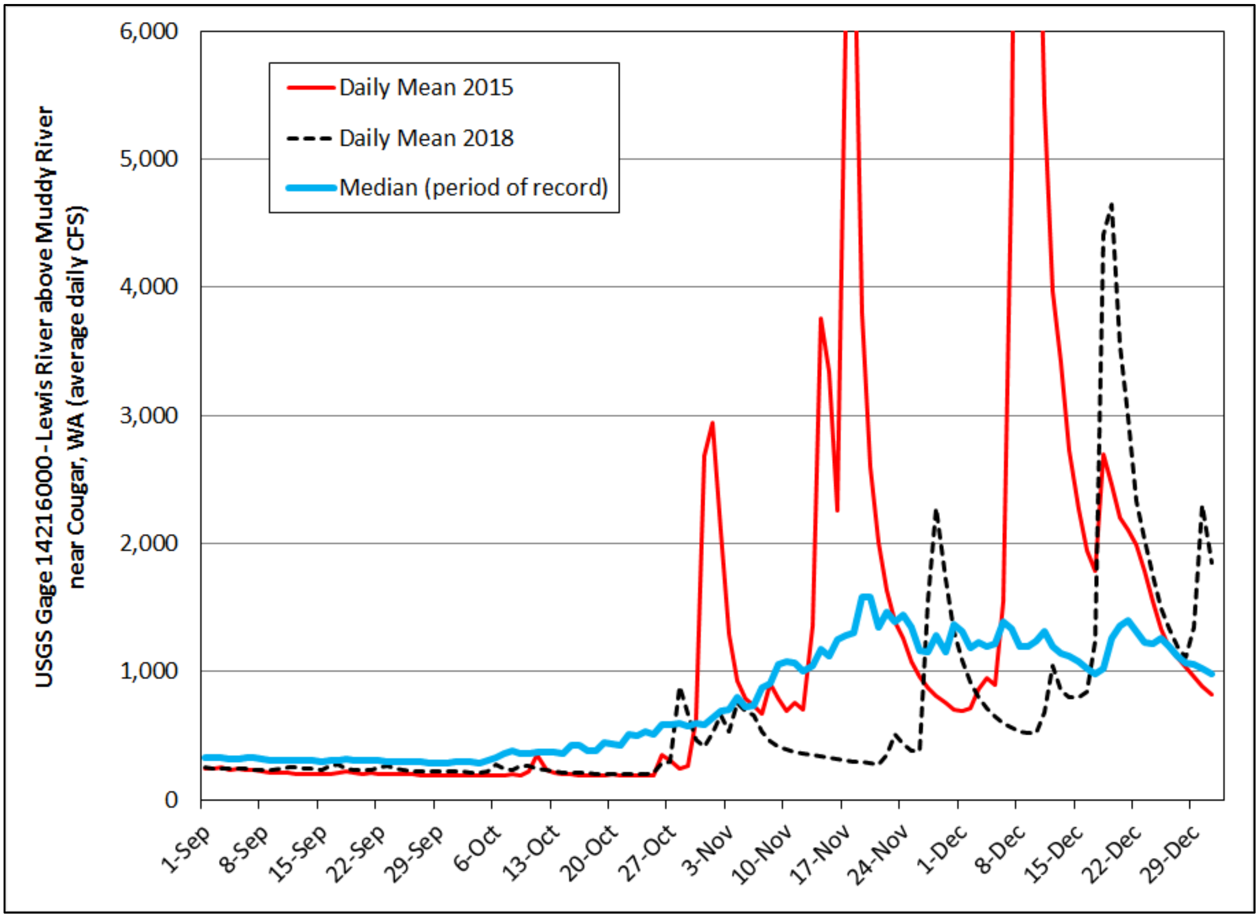

Figure 1. USGS North Fork Lewis River above Muddy River Gage average daily flow (cfs).

Methods

Field survey methods followed those described in the revised monitoring and evaluation plan (PacifiCorp and Cowlitz PUD 2017) with no deviations.

Results

Spring Chinook and Coho Transported Upstream

A total of 177 adult female Chinook were transported upstream to spawn during 2018. All of these fish potentially could have been observed during the survey period. Due to low returns, no Chinook were transported upstream during the 2012 and 2015 spawning season when the year-1 reach panel was previously surveyed.

A total of 2,452 adult female coho were transported upstream to spawn during 2018, which could have potentially been observed during the survey period (i.e. coho transported prior to December 31, 2018). However, 71% of coho adults were transported upstream after mid-November when seasonal road closures began to limit survey reach access, and 68% of coho were transported upstream after mid-December when high flows further reduced survey reach access and visibility. A total of 79 and 1,694 adult female coho were transported upstream to spawn during 2012 and 2015 (respectively); years when the year-1 panel was surveyed previously.

Spring Chinook Redd Counts

A total of 97 Chinook redds were observed in 2018 (Table 1). Of this total, 97% of redds were counted in the NF Lewis River mainstem reaches, and 77% of all Chinook redds were counted in the NF Lewis River mainstem within one mile of Lower Falls, which is a natural barrier to upstream migration. Live Chinook and/or carcasses were observed distributed along the Muddy River mainstem, but redds were only counted in one reach in the upper mainstem Muddy River between Smith and Clearwater creeks. No Chinook (lives, carcasses, or redds) were observed in tributaries to the Muddy River. Chinook were not observed in small tributaries of the NF Lewis River or Swift Reservoir due to low stream flows during the Chinook spawning season. Of note is that Chinook were not observed in the Pine Creek watershed even though weekly surveys were successfully conducted over the entire Pine Creek mainstem and in reaches of P1, P3, P7 and P8 during all of September and October.

The 2018 trend of spawning concentrated in the mainstem NF Lewis River with scattered spawning throughout the Muddy River watershed, and no spawning observed in the Pine Creek watershed is similar to the distribution observed during 2017, which is the first year when Chinook were transported upstream in substantial numbers. However, Chinook redds were distributed over a broader area in the mainstem NF Lewis River and Muddy River watersheds in 2017, likely due to higher stream flows during the 2017 Chinook spawning period (which approximated median flow conditions depicted in Figure 1).

Table 1. Spring Chinook spawning survey summary results (2018).

	2018 Spring Chinook					
	# Reaches in Panel	% Reaches Surveyed Sep	% Reaches Surveyed Oct	# Chinook (live + dead)	# of Redds	% Surveyed Reaches Occupied[f]
Muddy River Watershed	38	82%	82%	7	4	11%
Clear Creek	10[a]	70%	70%	0	0	0%
Clearwater Creek	6[b]	67%	67%	0	0	0%
EF Clearwater Creek	2	100%	100%	0	0	0%
Smith Creek	7[c]	86%	86%	0	0	0%
Muddy River mainstem	13[d]	92%	92%	7	4	23%
NF Lewis Watershed	20	100%	90%	184	93	40%
Chickoon	1	100%	100%	0	0	0%
Cussed Hollow Creek	1	100%	100%	0	0	0%
Pepper Creek	2	100%	100%	0	0	0%
Rush Creek	2[e]	100%	0%	0	0	0%
NF Lewis River mainstem	14	100%	100%	184	93	57%
Pine Creek Watershed	18	100%	100%	0	0	0%
P1 Creek	1	100%	100%	0	0	0%
P3 Creek	2	100%	100%	0	0	0%
P7 Creek	2	100%	100%	0	0	0%
P8 Creek	4	100%	100%	0	0	0%
Pine Creek mainstem	9	100%	100%	0	0	0%
Swift Reservoir Watershed	6	100%	100%	0	0	0%
Drift Creek	1	100%	100%	0	0	0%
Range Creek	1	100%	100%	0	0	0%
S10 Creek	1	100%	100%	0	0	0%
S15 Creek	2	100%	100%	0	0	0%
S20 Creek	1	100%	100%	0	0	0%
Grand Total	82	91%	89%	191	97	15%

[a] Three of 13 reaches were not accessible due to steep inaccessible canyon slopes.
[b] Two of six reaches were not accessible due to steep inaccessible canyon slopes.
[c] The most upstream reach is not logistically feasible to survey.
[d] One of 13 reaches was not accessible due to steep inaccessible canyon slopes.
[e] Rush Creek year-1 survey reaches are extremely steep (near 20% slope) and were not resurveyed in October for Chinook.
[f] A reach was determined to be occupied if a live Chinook, Chinook carcass, or Chinook redd was counted within the reach.

Coho Redd Counts

A total of 87 coho redds were counted during the 2018 survey season. Coho primarily spawned in Swift Reservoir tributaries (primarily S20 Creek), the mainstem of the North Fork Lewis River (primarily in side channels), and in P3 Creek (a small tributary of Pine Creek) (Table 1). Early coho spawning was hindered by extremely low stream flows that limited access to small streams typically used extensively by coho in prior years (such as the reservoir tributaries).

In 2015, only 21 live coho, 6 redds, and 2 carcasses were observed during the entire survey season (primarily in S20 Creek). However, surveys were greatly hindered due to the overall high flows and difficult/poor survey conditions, which persisted during the period when the majority of coho were transported upstream. In 2012 only 15 coho redds, 10 live coho, and 0 carcasses were observed scattered throughout available habitat (including the Pine, Muddy, reservoir tributaries, and mainstem NF Lewis River strata), but very few coho were transported upstream in 2012.

Table 2. Coho spawning survey summary results (Sep - December 2018).

	2018 Coho							
	# Reaches in Panel	% Reaches Surveyed Sep	% Reaches Surveyed Oct	% Reaches Surveyed Nov	% Reaches Surveyed Dec	# Coho (live + dead)	# of Redds	% Surveyed Reaches Occupied[h]
Muddy River Watershed	38	82%	82%	45%[f]	24%[f]	0	4	11%
Clear Creek	10[a]	70%	70%	0%	0%	0	0	0%
Clearwater Creek	6[b]	67%	67%	33%	0%	0	0	0%
EF Clearwater Creek	2	100%	100%	0%	0%	0	0	0%
Muddy River mainstem	7[c]	86%	86%	69%	69%	0	4	25%
Smith Creek	13[d]	92%	92%	86%	0%	0	0	0%
NF Lewis Watershed	20	100%	90%	90%	90%	29	42	60%
Chickoon	1	100%	100%	100%	100%	2	3	100%
Cussed Hollow Creek	1	100%	100%	100%	100%	0	0	0%
Pepper Creek	2	100%	100%	100%	100%	0	0	0%
Rush Creek	2[e]	100%	0%	0%	0%	0	0	0%
NF Lewis River mainstem	14	100%	100%	100%	100%	27	39	92%
Pine Creek Watershed	18	100%	100%	89%	50%[f]	16	12	39%
P1 Creek	1	100%	100%	100%	0%	0	0	0%
P3 Creek	2	100%	100%	100%	100%	13	4	50%
P7 Creek	2	100%	100%	100%	0%	0	0	0%
P8 Creek	4	100%	100%	50%	0%	0	0	0%
Pine Creek mainstem	9	100%	100%	100%	78%	3	8	67%
Swift Reservoir Watershed	6	100%	100%	100%	100%	121	29	60%
Drift Creek	1	100%	100%	100%	100%	0	1	100%
Range Creek	1	100%	100%	0%	0%	0	0	?[g]
S10 Creek	1	100%	100%	100%	100%	5	8	100%
S15 Creek	2	100%	100%	100%	100%	0	0	0%
S20 Creek	1	100%	100%	100%	100%	116	20	100%
Grand Total	82	91%	89%	70%	51%	166	87	36%

[a] Three of 13 reaches were not accessible due to steep inaccessible canyon slopes.

[b] Two of six reaches were not accessible due to steep inaccessible canyon slopes.

[c] The most upstream reach is not logistically feasible to survey.

[d] One of 13 reaches was not accessible due to steep inaccessible canyon slopes.

[e] Rush Creek year-1 survey reaches are extremely steep (near 20% slope) and were not resurveyed for coho after September.

[f] Seasonally closed roads and snow greatly limited access to reaches.

[g] Stream flows limited access to Range Creek during September and October so spawning potential was zero. However as flows increased in November and December, the Range Creek reach is within a steep gorge and not accessible by foot.

[h] A reach was determined to be occupied if a live coho, coho carcass, or coho redd was counted within the reach.

Spawn Timing

The first redd with active Chinook spawners present was observed on September 6 in the Muddy River, between Smith and Clearwater creeks. The NF Lewis River mainstem was first surveyed on September 7 and 30 Chinook redds were counted within 1 mile of Lower Falls (many occupied by live spawners). Based on observations of Chinook spawners, occupied redds, and carcasses (Table 3), and weekly redd counts (Table 4), the spawn timing of Chinook was likely late-August to early-October during the 2018 survey season.

Table 3. Key spawn timing observations

Timing Parameter	Chinook	Coho
1st live holder observed	9/7/18	10/24/18
1st live spawner observed	9/6/18	10/29/18
1st occupied redd observed	9/7/18	10/29/18
1st carcass observed	9/7/18	12/27/18
Last live holder observed	9/24/18	12/31/18
Last live spawner observed	9/26/18	12/31/18
Last carcass observed	10/4/18	12/31/18

The first coho redds observed with active coho spawners present were counted in P3 Creek (Pine Creek tributary) on October 29. A total of 50 live coho spawners and 11 new redds were counted in S20 Creek and 5 live holders were observed in P3 Creek on the last survey on December 31. Based on coho observations (Table 3) and redd counts (Table 4), the spawn timing of coho was likely late-October into January during the 2018 survey season.

Table 4. Percent of redds counted by survey week and species (spawn timing).

Survey Week	Total Chinook Redds	% Total Chinook Redds	Total Coho Redds	% Total Coho Redds
2-Sep	33	34%	0	
9-Sep	27	28%	0	
16-Sep	13	13%	0	
23-Sep	16	16%	0	
30-Sep	2	2%	0	
7-Oct	6	6%	0	
14-Oct	0	0%	0	0%
21-Oct	0		1	1%
28-Oct	0		8	9%
4-Nov	0		7	8%
11-Nov	0		27	31%
18-Nov	0		4	5%
25-Nov	0		9	10%
2-Dec	0		7	8%
9-Dec	0		2	2%
16-Dec	0		0	0%
23-Dec	0		11	13%
Dec 30-Dec 31	97		11	13%
Grand Total	**97**		**87**	

It is important to reiterate that 71% of coho were transported upstream after mid-November when seasonally closed roads and snow limited access to a large portion of the Muddy River watershed. In addition, 68% of coho were transported upstream after

December 14 (Figure 2) when survey conditions were further hindered by high flows causing poor visibility and unsurveyable conditions in most reaches. These factors affect redd detection probability and skew the spawn timing determination to earlier in the spawning season when visibility and survey conditions were better, instead of when most coho were present and likely spawned (late-December into January).

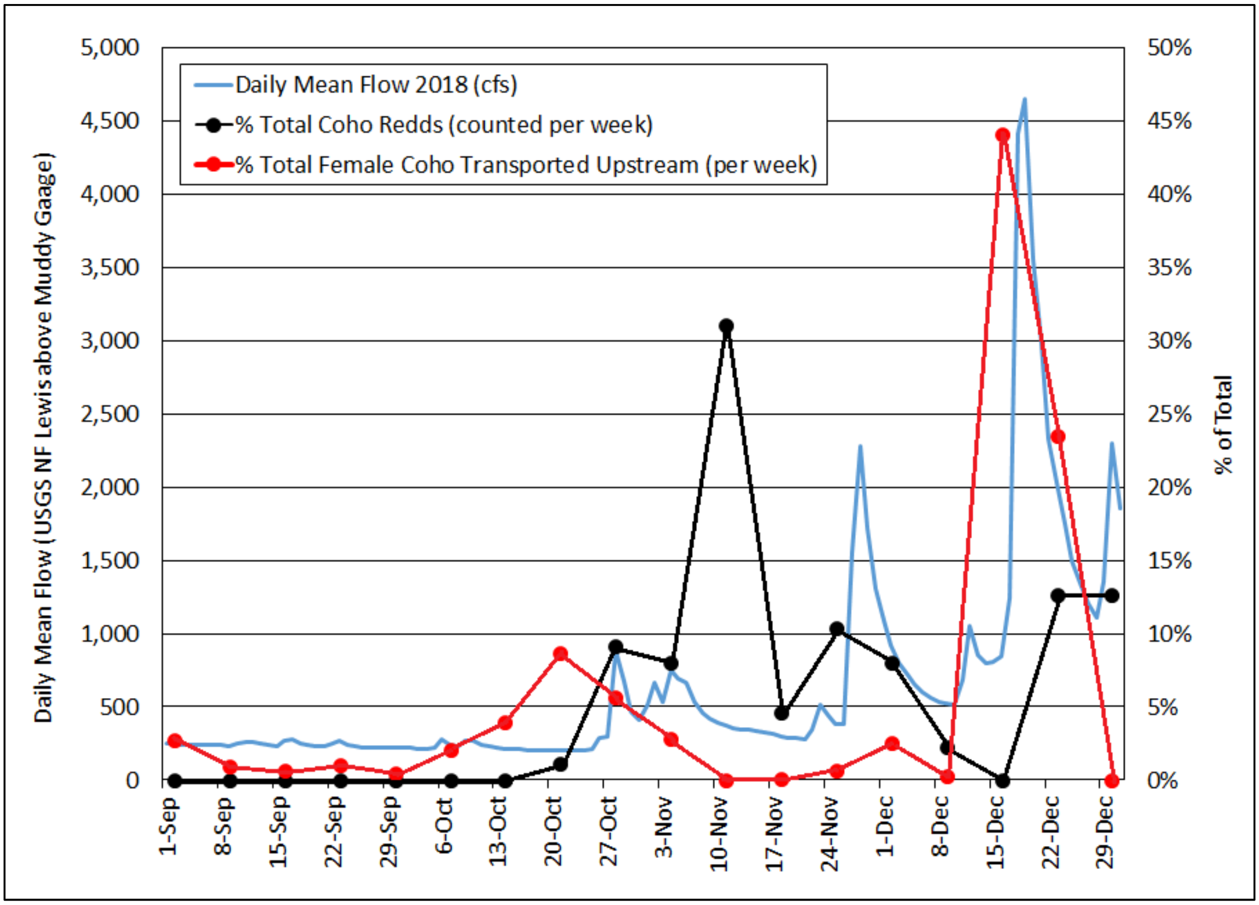

Figure 2. Coho redd count timing vs. adult female coho transport timing vs flow.

Estimate of Total Redds

Redd counts were used to make estimates of total redds by watershed (see report from Leigh Ann Starcevich, PhD, Biometrician, West Inc., 2019). Total Chinook redd estimates incorporating a detection probability ranging from 0.75 to 0.85, as specified in PacifiCorp and Cowlitz PUD (2017), are presented in Table 5. Total coho redd estimates incorporating a redd detection probability of 0.3 to 0.6, as specified in PacifiCorp and Cowlitz PUD (2017) are presented in Table 6. Total coho redd estimates were made using surveys through December 14 due to reach inaccessibility and poor visibility during the 2nd half of December.

Table 5. 2018 total spring Chinook redd estimates.

	2018 Total Redd Estimate	95% Confidence Interval
Muddy River Watershed	21	0 - 43
NF Lewis River Watershed	363	46 - 715
Pine Creek Watershed	0	0
Swift Reservoir Watershed	0	0
Grand Total	384	51 to 737

Table 6. 2018 total coho redd estimates through December 14, 2018 surveys.

	2018 Total Redd Estimate	95% Confidence Interval
Muddy River Watershed	40	11 - 79
NF Lewis River Watershed	246	130 - 402
Pine Creek Watershed	55	8 - 114
Swift Reservoir Watershed	138	11 - 284
Grand Total	479	260 - 774

Estimate of Proportion of Transported Female Spring Chinook and Coho that Spawned

Using the adjusted estimate of total redds based on the range of assumed detection probability and assuming one spawning female per redd, yields an estimate of 2.17 (bootstrap 95% confidence interval of 0.29 to 4.16) as the proportion of transported female Chinook that spawned in 2018 (Starcevich 2019). The proportion of transported female Chinook estimated to have spawned in 2017 was 1.03 (bootstrap 95% confidence interval of 0.56 to 1.50). The large confidence interval for the 2018 estimate is caused by the very patchy nature of observed Chinook spawning (i.e., high variation in redd counts between reaches). This variation was much higher in 2018 than 2017 and is probably due to low stream flows that concentrated Chinook into fewer reaches. Proportions of 1.0 (or greater) suggest that all transported females spawned (assuming 1 redd per female). Proportions substantial greater than 1.0 indicate that actual detection probabilities are higher than assumed and/or that female Chinook build more than 1 redd on average.

The estimate of the proportion of spawning coho females was made for the total number of coho transported upstream prior to December 14 to account for reach inaccessibility and poor visibility during the 2nd half of December. The proportion of female coho (transported upstream prior to December 14) estimated to have successfully spawned in 2018 is 0.61 (bootstrap 95% confidence interval of 0.33 to 0.98), which is similar to estimates made over the previous 4-year period (Table 7).

Table 7. Estimates of the proportion of spawning coho females by year.

	Estimated Proportion of Spawning Female Coho	95% Confidence Interval
2018	0.61	0.33 - 0.98
2017	0.34[a]	0.20 - 0.54
2016	0.69	0.25 - 1.20
2015	No Estimate	No Estimate
2014	0.50	0.23 - 0.86

[a] Likely substantially underestimated due to survey limitations in areas known to be heavily used by coho for spawning in November and December. NF Lewis River mainstem surveys were limited due to high flows and Swift Reservoir tributary surveys were limited due to low reservoir conditions, which precluded boat access.

Discussion and Conclusions

Redd counts and estimates of spawning success suggest that most (if not all) adult Chinook females transported upstream during 2018 spawned, similar to 2017 results. The estimated proportion of spawning females over 1.0, suggests that our detection probability was probably near 100% in 2018 due to low stream flows and excellent visibility; female spring Chinook may build more than one redd; and/or some redds identified as Chinook redds, may have actually been coho redds. However, misidentification is probably less likely due to the clear spawner/carcass observations separating the Chinook vs coho spawn timing described in Table 2.

Similar to 2017, Chinook adults in 2018 appear to have distributed several miles upstream within the Muddy River mainstem, upstream of the Clearwater Creek confluence, and throughout the mainstem NF Lewis River, being most highly concentrated in the upper mainstem NF Lewis River. However, unusually low stream flows appear to have limited Chinook spawning use of smaller tributary streams. Chinook do not appear to prefer Pine Creek for spawning as no live Chinook, Chinook carcasses, or potential Chinook redds were observed in the entire Pine Creek mainstem in 2017 and 2018, when weekly surveys were conducted over the entire mainstem during the Chinook spawning season.

Unusually low flows in the reservoir tributaries from September to late-November likely limited spawning habitat for early-Coho, which have been shown to widely use the reservoir tributaries for spawning in previous years. Once flows rose due to heavy rainstorms, many coho were observed spawning in small tributaries, particularly S20 Creek, after late-coho were transported upstream in large numbers.

Of note this spawning survey was designed to quantify early-coho and spring Chinook spawning. The decision to transport late-coho upstream in substantial numbers was not contemplated in this survey design. Surveys to quantify late-coho spawning abundance, timing, and distribution will likely always be problematic due to inherent survey limitations such as seasonally closed roads, typical snow accumulation, seasonally low reservoir elevation that precludes boat access to reservoir tributaries, and typical large storms that decrease stream visibility.

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Redd Estimates from Surveys Conducted on the Upper North Fork Lewis River: 2018

Analysis Report

Prepared for:

Meridian Environmental, Inc.

2136 Westlake Ave. N Seattle, WA 98109

Prepared by:

Leigh Ann Starcevich
Western EcoSystems Technology, Inc.
2725 NW Walnut Blvd. Corvallis, OR 97330

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INTRODUCTION

Meridian Environmental, Inc. was contracted by PacifiCorp to conduct spawning surveys for anadromous fish transported upstream of Swift Dam (North Fork Lewis River watershed). Redd surveys were conducted in 2018 to monitor spawning of anadromous fish species (coho and Chinook salmon). Transported anadromous fish had access to any of four stream networks: the Muddy River, North Fork Lewis River, Pine Creek, and several smaller independent tributaries to Swift Creek Reservoir. Using the data from a survey designed in cooperation with Leigh Ann Starcevich in 2012, Western EcoSystems Technology, Inc. (WEST) was contracted to provide estimates of the total numbers of coho and Chinook redds and the proportions of transported coho and Chinook females that successfully spawned. In this report, we provide estimates for spawning parameters from the 2018 surveys for both coho and Chinook salmon.

STUDY DESIGN

In 2012, a stratified random one-stage cluster sampling design was developed. PacifiCorp planned to monitor all accessible habitat upstream of Swift Dam over a three-year period. The sampling frame of all 73.98 miles of potential anadromous fish habitat was identified for the four stream networks. Each year, roughly 25 miles of the stream networks would be surveyed. Each stream network served as a stratum so that network-level inference could be obtained. In 2016, an additional 3.12 miles of stream network in the Muddy River, North Fork Lewis River, and Swift Creek Reservoir tributaries were determined to be part of the target population and were added to the sampling frame. These new streams added to the frame were not originally identified as potentially accessible to transported anadromous fish or became accessible after fish barriers were removed (culverts) after the original 2012 sample design was developed. These reaches were allocated across all three temporal revisit panels and those falling in the 2nd year revisit panel were surveyed in 2016.

Streams vary in length across the target population, ranging from 0.1 to 13.8 miles. An additional stratum was defined to allocate sampling effort across Short reaches (less than 8 miles long) and Long reaches (at least 8 miles long). A stream segment (e.g., reach), the sampling unit of interest for this study, was defined as continuous and non-overlapping length of stream up to 0.3-mile long (Table 1). Stream segments were combined into clusters consisting of one, two, or three stream segments. Clustering within each stratum allowed for a reduction in travel time among sampling units and an increase in survey efficiency. For each sampled segment, counts of live anadromous fish, redds, and carcasses were collected. The four stream networks in the sampling frame totaled 73.98 miles of stream network after removing reaches identified in 2012 as containing barriers to fish passage and adding additional accessible reaches in 2016.

Table 1. Number of stream reaches by stratum.

Stratum	Watershed	Length stratum	Number of 0.1- to 0.3-mile stream segments	Total length (miles)
1	Muddy River	Long	77	23.10
2	Muddy River	Short	43	12.61
3	NF Lewis River	Long	43	12.90
4	NF Lewis River	Short	17	4.76
5	Pine Creek	Long	27	8.03
6	Pine Creek	Short	26	7.56
7	Swift Creek Reservoir Tributaries	Short	20	5.02

ANALYSIS METHODS

Estimates of totals were calculated with a ratio estimator for a one-stage cluster sample of clusters of unequal size (Lohr 1999). The density (*y*) of the outcome of interest (count of redds or carcasses) was calculated for each segment by dividing the count by the length of the segment. Define the following terms as:

N = number of clusters in the population,

n = number of clusters in the sample,

M_i = number of segments in the i^{th} cluster,

m_i = the number of sampled segments in the i^{th} cluster,

$K = \sum_{i=1}^{N} M_i$ = the total number of segments in the population, and

y_{ij} = the j^{th} outcome in the i^{th} cluster.

The segment-level densities were then used to obtain an estimate of the total (redds or carcasses) as follows:

$$\hat{t}_r = K\hat{\bar{y}}_r,$$

$$\text{where } \hat{\bar{y}}_r = \frac{\sum_{i=1}^{n} t_i}{\sum_{i=1}^{n} M_i} \text{ and } t_i = \frac{M_i \sum_{j=1}^{m_i} y_{ij}}{m_i}.$$

The standard error of the estimate of the total is calculated as:

$$\mathrm{SE}\left(\hat{t}_r\right) = N\sqrt{\left(1 - \frac{n}{N}\right)\frac{1}{n}\frac{\sum_{i=1}^{n} M_i^2\left(\bar{y}_i - \hat{\bar{y}}_r\right)^2}{n - 1}},$$

where $\bar{y}_i = \frac{\sum_{j=1}^{m_i} y_{ij}}{m_i}$.

The estimated number of redds was further adjusted for imperfect detection probabilities. The rate of coho redd detection has been estimated as ranging between 0.3 and 0.6 (PacifiCorp and Cowlitz PUD 2017). For Chinook redds, the detection probability was approximated as 0.8 based on a detailed evaluation of Chinook redd visibility conducted during the 2017 survey season and a range of 0.75 to 0.85 was used to account for some uncertainty in the estimate. These ranges were applied in a bootstrap application to calculate an estimate of the number of redds that accounted for imperfect detection and to obtain 95%-confidence intervals based on the bootstrap. Each bootstrapped sample was obtained by bootstrapping clusters within each stratum then combining the samples across samples and calculating the estimated number of redds with the ratio estimator. Then a detection probability was selected from a uniform distribution within each detection probability range, and the estimated number of redds was inflated by this factor. For a set of 1000 bootstrap estimates, the 2.5%- and 97.5%-percentiles were used within and across strata to obtain bootstrap confidence intervals.

The proportion of spawning females was calculated as the estimated number of redds (after accounting for imperfect redd detection) divided by the total number of transported females for each species, and confidence intervals were constructed from the variance obtained from the ratio estimator. This calculation was based on an assumption of that each redd represented a single spawning female. Given this assumption, the known number of transported females for each species represents the known total number of females in the population upstream of Swift Dam. Therefore, the estimated number of redds is equivalent to the estimated number of spawning females. Given the total number of transported females (*f*), the proportion of spawning females, $\hat{p}_r$, and its standard error were calculated as:

$$\hat{p}_r = \frac{\hat{t}_r}{f} \text{ and } \mathrm{SE}\left(\hat{p}_r\right) = \frac{\mathrm{SE}\left(\hat{t}_r\right)}{f}.$$

RESULTS

In 2018, some reaches were not accessible during the period after the majority of the coho were transported upstream (Table 2) for reasons such as seasonally-closed roads (22 reaches) and prohibitive distance (1 reach). At total of 7 reaches were inaccessible due to steep slopes precluding safe access to the stream channel from above (which affected both coho and Chinook surveys). We treat these reaches as missing completely at random and extrapolate results from surveyed reaches to unsurveyed reaches to obtain estimates of total redds. Because seasonal road closures limited access to a large proportion of the survey area and large storms that limited visibility after December 14, 2018 and due to the large number of coho transported upstream after December 14, 2018, we examine the coho redd count data collected over the entire survey season as well as only until December 14, 2018.

Table 2: Accessible and inaccessible stream miles by stratum and species for 2018 surveys.

Stream Network Stratum	Length Stratum	Coho		Coho (through 12/ 14/18)		Chinook	
		Inaccessible	Accessible	Inaccessible	Accessible	Inaccessible	Accessible
Muddy	L	4.20	2.70	1.50	5.40	1.20	5.70
Muddy	S	4.50	0.00	1.50	3.00	0.94	3.56
NF Lewis	L	0.00	4.20	0.00	4.20	0.00	4.20
NF Lewis	S	0.00	1.84	0.00	1.84	0.00	1.84
Pine	L	0.00	2.70	0.00	2.70	0.00	2.70
Pine	S	0.00	2.71	0.00	2.71	0.00	2.71
Swift	S	0.10	1.50	0.10	1.50	0.00	1.60
TOTAL		8.80	15.65	3.10	21.35	2.14	22.31

2018 Redd Estimates

Both coho and spring Chinook salmon redds were surveyed in 2018, and the results of each analysis are presented below.

Coho Salmon (surveys conducted through December 31, 2018)

A total of 21.35 stream miles were surveyed in 2018, but only 15.65 miles were accessible throughout the entire survey period. Most (61%) of coho were transported upstream after mid-December when rains affect survey conditions and access becomes more limited. A total of 30 reaches, 29 of which occurred in the Muddy River, were not surveyable after the majority of coho were transported upstream in December. No reaches in the "Short" stratum in the Muddy River were accessible during this time, so this stratum was unrepresented in the 2018 survey. Because this stratum has exhibited very low redd density over the past years of surveys (Table 3), no extrapolation was made to this stratum resulting in an estimate of total redds that is conservative. The estimated numbers of redds by stratum and across strata for coho salmon are provided in Table 4. A total of 87 coho redds were observed, resulting in an estimate of 294 total coho redds (SE = 74, 95%-confidence interval: 148, 440). Adjusting for imperfect detection increased the estimated number of redds to 688 (95% bootstrap interval: 375, 1122).

Coho Salmon (surveys conducted until December 14, 2018)

Given the large proportion of the Muddy River that was inaccessible after December 14, 2018, surveys occurring before that date were examined to obtain a second set of coho redd estimates for comparison (Table 5). A total of 65 coho redds were observed during this period, resulting in an estimate of 207 total coho redds (SE = 44, 95%-confidence interval: 120, 294). Adjusting for imperfect detection increased the estimated number of redds to 479 (95% bootstrap interval: 260, 774).

Table 3. Unadjusted and adjusted estimates of total coho salmon redds by and across strata for 2014, 2016, and 2017.

Year	Stream Network Stratum	Length Stratum	Total Redds Observed	Total Estimate	Standard Error	95%-CI Lower Bound	95%-CI Upper Bound	Adjusted Total Estimate	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound	Est. Density	Est. Adj. Density
2014	Muddy	L	37	158.28	22.44	114.30	202.25	365.77	158.83	620.75	6.85	15.83
2014	Muddy	S	4	15.28	9.05	-2.45	33.02	35.06	0.00	76.31	1.21	2.78
2014	NF Lewis	L	160	458.67	249.68	-30.71	948.04	1059.04	166.47	2151.58	35.56	82.10
2014	NF Lewis	S	28	108.51	65.39	-19.65	236.67	246.24	54.46	516.20	22.80	51.73
2014	Pine	L	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2014	Pine	S	3	9.45	8.11	-6.45	25.35	22.07	0.00	50.15	1.25	2.92
2014	Swift	S	50	167.33	58.74	52.21	282.46	382.31	152.10	648.54	33.33	76.16
2016	Muddy	L	18	51.33	8.83	34.02	68.64	118.46	24.33	235.99	2.22	5.13
2016	Muddy	S	1	3.23	2.76	-2.18	8.65	7.49	0.00	16.98	0.26	0.59
2016	NF Lewis	L	29	311.75	101.24	113.32	510.18	582.07	0.00	1260.29	24.17	45.12
2016	NF Lewis	S	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2016	Pine	L	16	85.65	34.92	17.20	154.10	186.71	47.02	380.05	10.67	23.25
2016	Pine	S	11	92.40	89.66	-83.34	268.14	215.24	0.00	575.45	12.22	28.47
2016	Swift	S	103	456.99	108.10	245.10	668.87	1036.33	322.61	2004.08	91.03	206.44
2017	Muddy	L	32	136.89	26.73	84.50	189.27	315.91	96.83	596.28	5.93	13.68
2017	Muddy	S	3	9.01	5.42	-1.62	19.64	20.50	0.00	45.18	0.71	1.63
2017	NF Lewis	L	55	157.67	74.80	11.06	304.27	370.33	109.50	710.51	12.22	28.71
2017	NF Lewis	S	13	40.84	14.98	11.49	70.20	94.87	34.98	176.49	8.58	19.93
2017	Pine	L	1	2.97	2.42	-1.77	7.71	6.85	0.00	15.89	0.37	0.85
2017	Pine	S	4	12.60	8.18	-3.43	28.63	29.99	0.00	62.78	1.67	3.97
2017	Swift	S	32	146.42	38.32	71.30	221.53	339.05	189.63	533.74	29.17	67.54

Table 4. Unadjusted and adjusted 2018 estimates of total coho salmon redds by and across strata for surveys conducted through December 31, 2018.

Stream Network Stratum	Length Stratum	Total Redds Observed	Total Estimate	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound	Adjusted Total Estimate	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound
Muddy	L	4	34.22	25.67	51.33	78.76	44.19	124.41
Muddy	S	*	-	-	-	-	-	-
Muddy	All	4	34.22	25.67	51.33	78.76	44.19	124.41
NF Lewis	L	39	119.79	76.44	177.38	282.54	151.08	481.08
NF Lewis	S	3	7.68	0.00	15.35	18.01	0.00	43.72
NF Lewis	All	42	127.46	85.65	189.87	300.55	168.14	499.94
Pine	L	8	23.79	8.92	53.53	55.31	15.42	106.08
Pine	S	4	11.20	0.00	20.16	26.36	0.00	60.29
Pine	All	12	34.99	8.92	56.43	81.68	16.94	158.94
Swift	S	29	97.05	5.58	175.70	227.50	13.16	488.89
All	**All**	87	293.73	192.10	402.74	688.48	374.55	1121.72

* Stratum inaccessible.

Table 5. Unadjusted and adjusted 2018 estimates of total coho salmon redds by and across strata for surveys conducted through December 14, 2018.

Stream Network Stratum	Length Stratum	Total Redds Observed	Total Estimate	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound	Adjusted Total Estimate	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound
Muddy	L	4	17.11	6.42	25.67	39.51	11.31	79.11
Muddy	S	*	-	-	-	-	-	-
Muddy	All	4	17.11	6.42	25.67	39.51	11.31	79.11
NF Lewis	L	32	98.29	64.50	146.20	227.86	119.70	373.18
NF Lewis	S	3	7.68	0.00	15.35	18.12	0.00	42.65
NF Lewis	All	35	105.96	68.69	156.64	245.98	130.47	402.13
Pine	L	7	20.82	0.00	53.53	48.12	0.00	103.31
Pine	S	1	2.80	0.00	6.30	6.51	0.00	15.47
Pine	All	8	23.62	4.20	57.13	54.63	7.62	113.83
Swift	S	18	60.24	5.58	100.40	138.46	10.64	284.12
All	**All**	65	206.93	135.03	282.14	478.59	260.14	773.58

* Stratum inaccessible.

Chinook Salmon

Spring Chinook spawning was observed to occur from September to mid-October, 2018. Stream reaches during this time period were not affected by site inaccessibility due to closed roads and poor visibility due to large storms as the coho redd surveys were. However, 13 reaches were determined to be too low to sustain spawning. These reaches were treated as frame error since they did not meet the target population definition of spawnable water. No redds were observed in three strata that exhibited frame error, so the estimates were zero and not affected by the frame error. A total of 22.31 stream miles were surveyed throughout the spring Chinook spawning season. The estimated numbers of redds by stratum and across strata for Chinook salmon are provided in Table 6. A total of 97 spring Chinook redds were observed for an estimate of 302 total redds (SE = 170, 95%-confidence interval: -31, 635). Adjusting for imperfect detection increased the estimated number of redds to 384 (95% bootstrap interval: 51, 737). The imprecision of the estimates are due to highly variable redd counts between reaches within the North Fork Lewis River stratum.

Estimated Proportion of Spawning Females

Using the estimates of total redds, the proportion of spawning females is calculated assuming one spawning female per redd. Dividing the estimated number of redds by the number of transported females per year, the estimated proportions of transported female salmon that spawned are calculated (Table 7). The estimated proportion of spawning females for coho using the complete survey season is 0.12 (90%-CI: 0.06, 0.18) and is 0.28 (90%-CI: 0.15, 0.46) when the estimated is adjusted for imperfect detection. When only the surveys conducted through December 14, 2018 are used, the estimated proportion of spawning coho females is 0.26 (90%-CI: 0.15, 0.37) and when accounting for impact detection is 0.61 (90%-CI: 0.33, 0.98). The estimated proportion of spawning Chinook females is 1.71 (90%-CI: -0.18, 3.59) and is 2.17 (90%-CI: 0.29, 4.16) when the estimated is adjusted for imperfect detection. Note that the estimates of Chinook redds exceed the number of transported female Chinook, so the estimated proportions of spawning females exceed 1.

Table 6. Unadjusted and adjusted 2018 estimates of total Chinook salmon redds by and across strata.

Stream Network Stratum	Length Stratum	Total Redds Observed	Total Estimate	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound	Adjusted Total Estimate	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound
Muddy	L	4	16.21	0	34.22	20.65	0.00	42.99
Muddy	S	0	0	0	0	0	0	0
Muddy	All	4	16.21	0	34.22	20.65	0.00	42.99
NF Lewis	L	93	285.64	37.62	580.50	362.91	46.21	715.45
NF Lewis	S	0	0	0	0	0	0	0
NF Lewis	All	93	285.64	37.62	580.50	362.91	46.21	715.45
Pine	L	0	0	0	0	0	0	0
Pine	S	0	0	0	0	0	0	0
Pine	All	0	0	0	0	0	0	0
Swift	S	0	0	0	0	0	0	0
All	**All**	97	301.85	37.62	580.50	383.56	51.42	736.71

Table 7. Unadjusted and adjusted estimates of the proportion of spawning females by year and species.

Year	Species	Females Transported	Est. Proportion of Spawning Females	95%-CI Lower Bound	95%-CI Upper Bound	Adjusted Est. Proportion of Spawning Females	Bootstrap 95%-CI Lower Bound	Bootstrap 95%-CI Upper Bound
2018	Coho	2452	0.12	0.08	0.16	0.28	0.15	0.46
2018	Coho (through 12/14/18)	789	0.26	0.17	0.36	0.61	0.33	0.98
2018	Chinook	177	1.71	0.21	3.28	2.17	0.29	4.16

DISCUSSION AND CONCLUSIONS

Design-based estimates of coho and Chinook salmon redds were obtained from a stratified one-stage cluster sample and ratio estimation. Assuming that redd detection ranges between 0.3 and 0.6 for coho salmon and 0.75 to 0.85 for Chinook salmon, the redd estimates were adjusted to account for imperfect detection. The adjusted estimate of total redds provided an estimate of spawning females assuming that one spawning female occurs per redd. This assumption is violated if spawning females build redds on top of existing redds, causing the total number of redds to be underestimated. Violation of this assumption results in underestimation of the total number of redds and the proportion of spawning females. In addition, female spawners may build more than one redd, causing the estimate of total female spawners to be overestimated. Based on the Chinook spawning analysis for 2017 and 2018, it appears that the redd: female ratio is probably higher than one.

Nonresponse was particularly impactful for the 2018 coho redd surveys due to late transport of the majority of coho upstream after a large proportion if the survey area is inaccessible due to seasonally closed roads and unsurveyable conditions due to large storm events. Assuming that the missingness is completely at random and not related to the number of redds in a reach, an implicit assumption of this analysis is that the mean redd density in the surveyed reaches is equal to the mean redd density in non-surveyed reaches. Violation of this assumption may result in overestimation or overestimation of the total number of redds depending on the differences between redd counts in the surveyed and unsurveyed reaches.

For Chinook, the estimates of the proportion of spawning females exceeds 1. This indicates the considerable uncertainty introduced when nonsampling error such as imperfect detection and nonresponse occurs. The issues of nonresponse and imperfect detection probabilities may impact both the accuracy and precision of estimates of total redds and the proportion of spawning females. These estimates may be improved by more detailed modeling of redd detection by reach-level environmental attributes that impact detection such as water depth, turbidity, or stream size. However, such detailed models can be costly and time-consuming to develop and may ultimately not improve estimates depending on results. Reducing the number of reaches missed during a survey year would greatly improve the accuracy of redd estimates, especially in reaches known to have particularly high or low density. If surveys can be conducted as soon as is safely possible and when stream visibility is conducive, then accurate redd estimates may still be attainable during high-water years. However, due to seasonally closed roads and the propensity for large storms and snow to limit visibility and stream access, missing reach survey issues will likely continue to apply to redd count estimates for coho transported upstream after mid-November each year.

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