Lewis River Fish Passage Program
2019 Annual Report (*Final*)

Monitoring and Evaluation (M&E) Plan Metrics

FERC Project Nos. 935, 2071, 2111 and 2213

Out-migrating spring Chinook salmon smolt captured at the Swift Reservoir Floating Surface Collector
Photo by Chris Karchesky

PacifiCorp
&
Public Utility District No.1 of Cowlitz County

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ACRONYMS AND ABBREVIATIONS

ACC	Aquatics Coordinating Committee
ATE	Adult Trap Efficiency
ATS	Aquatic Technical Subgroup
AWS	Auxiliary Water Supply
BWT	Blank Wire Tag
CE	Collection Efficiency
cfs	Cubic Feet Per Second
Cowlitz PUD	Public Utility District No. 1 of Cowlitz County
CWT	Coded Wire Tag
EA	Electro-Anesthesia
ESA	Endangered Species Act
FCE	Fish Collection Efficiency
FERC	Federal Energy Regulatory Commission
FL	Fork Length
fps	Feet per Second
Fry	A recently hatched fish that has reached the stage where its yolk-sac has almost disappeared and its swim bladder is operational to the point where the fish can actively feed for itself. Juveniles referred to as fry are <60 mm based on ability to safely tag.
FSC	Swift Floating Surface Collector
ft	Foot
H&S	Hatchery and Supplemental Plan or Subgroup
HR	Hatchery returns
LWS	Ladder Water Supply
mm	millimeter
M&E	Monitoring and Evaluation
NMFS	National Marine Fisheries Service
NTS	Net Transition Structure
ODS	Overall Downstream Survival
Parr	A young salmonid that is older than a fry and younger than a smolt, having dark marks (i.e., parr marks) on their sides. Juveniles referred to as parr generally range in size from 60 to 120 mm.
PIT	Passive Integrated Transponder tag
Project	Lewis River Hydroelectric Project
PTAGIS	Pacific Northwest Regional PIT Tag Database
RMIS	Regional Mark Information System
ROV	Remotely Operated Vehicle
SA	Settlement Agreement
Smolt	A juvenile salmon that is ready to migrate out to the sea, smolts can be described as losing their camouflage bars (i.e., parr marks) and are in the process of physiological changes that allow them to survive a shift from freshwater to saltwater. Smotls are silvery in color and shed scales readily. Smolts can range from 120 to 300 mm depending on fish species.
UPS	Upstream Passage Survival
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

Utilities	PacifiCorp and Public Utility District No. 1 of Cowlitz County
UW	University of Washington
WDFW	Washington Department of Fish and Wildlife
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 that are outlined in the current Lewis River Aquatic Monitoring and Evaluation Plan[1] (M&E Plan) during 2019. The M&E Plan was developed as part of the Lewis River Settlement Agreement (SA) to evaluate performance measures outlined in the new FERC License for the Lewis River Hydroelectric Project, which was issued on June 26, 2008 to PacifiCorp and the Public Utility District No. 1 of Cowlitz County (Utilities). 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 or where further implemented in 2019. The following is a brief summary of relevant performance metrics documented in this report:

Description	M&E Obj.	Performance Goal	2019 Data	Summary
Number of Juveniles Passing Eagle Cliff During Screw Trap Operations	Obj. 7 Task 7.1	Monitoring	154,378 coho 12,981 steelhead 48,594 Chinook 1,053 cutthroat	Estimates of the total number of juvenile coho, Chinook, steelhead, and cutthroat were made over a 20-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	213,531 coho 36,463 steelhead 44,186 Chinook 12,089 cutthroat	Estimates of the total number of juvenile coho, steelhead, and cutthroat that entered Swift Reservoir during 2019.
Number of Fish Collected at the Swift Floating Surface Collector (FSC)	Obj. 6	Monitoring	99,057 coho 3,021 steelhead 10,951 Chinook 948 cutthroat	A total 118,612 salmonids were captured by the FSC in 2019. Of these fish, 111,702 were transported and released downstream of Merwin Dam.
Juvenile Migration Timing	Obj. 8	Monitoring	Various	Overall, the run timing in 2019 followed a normal frequency distribution, with peak migration occurring in late-May and a minor peak in late-October. Over 90% of all fish collected at the FSC in 2019 were collected between April 1 and June 30.
FSC Collection Efficiency (CE)	Obj. 2	Juvenile Collection Efficiency ≥ 95%	Coho 64% Chinook 51% Steelhead 27%	In 2019, CE was evaluated with acoustic transmitters. Estimates of efficiency among coho and Chinook were the highest observed since the commissioning of the FSC in 2012; however, the 95% collection efficiency standard was not met in 2019 for any species.
Swift FSC Injury	Obj. 5	Smolt and Fry ≤ 2%	Fry (0.81%) Smolt (0.11%)	Annual injury rates for all juvenile salmonid species met the required performance standard of 2.0%.

[1] The methods used in this report follow the revised methods for the M&E Plan dated 2017 (PacifiCorp and Cowlitz PUD 2017).

Description	M&E Obj.	Performance Goal	2018 Estimate	Summary
Swift FSC Survival	Obj. 4	Fry ≥ 98.0% Smolt ≥ 99.5%	Fry (98.0%) Smolt (99.7%)	The survival rate for salmonid fry (S_{COL}) met the 98% performance standard in 2019. However, the survival rate for smolts (CS) did not. (Parr were combined with smolt to derive estimates of CS for smolt).
Overall Downstream Survival (ODS)	Obj. 1	≥ 80%	Coho 42.3% Chinook 24.4% Steelhead 8.2% Cutthroat 7.6%	During 2019, 1,064 coho, 280 steelhead, 51 cutthroat, and 223 Chinook were tagged and released for the ODS study. Of these fish, 481 coho, 56 Chinook, 23 steelhead, and 4 cutthroat were recaptured at the FSC and passed downstream. These out-migrants were used to calculate ODS.
Number of Adult Fish Collected at the Merwin Fish Collection Facility	Obj. 11	Monitoring	Various	A total 8,495 fish were captured at the Merwin Trap in 2019. A total of 1,009 blank wire tag winter steelhead, 115 spring Chinook, 3,086 early coho, 2,501 late coho, and 45 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) 99.7% Coho (N) 99.9% Chinook 94.5% Steelhead 99.8% Cutthroat 100%	Ten early (S) coho mortalities were observed, resulting in a 99.7 percent UPS. One late (N) coho mortality was observed, resulting in a UPS of 99.9 percent. Six spring Chinook were recorded as mortalities resulting in a UPS of 94.5 percent. Two blank wire tag (BWT) winter steelhead mortalities were observed resulting in a UPS of 99.8 percent. No cutthroat mortalities were observed giving a UPS of 100 percent.
Adult Trap Efficiency (ATE)	Obj. 10	≥ 98%	Steelhead naïve 95% Steelhead non-naïve 85%	A fifth year of evaluation was completed in 2019 for BWT winter steelhead. The study had two main study groups, naïve and non-naïve. Naïve being fish that had not been captured at the Merwin Trap previously and non-naïve being fish that had been previously caught and tagged at the Merwin Trap and released downstream. The resulting ATE was 95% for naïve fish and 85% for non-naïve fish. Spring Chinook and coho ATE metrics were not studied in 2019.

1.0 INTRODUCTION

The Lewis River Hydroelectric Project (Project) begins approximately 10 miles east of Woodland, Washington (Figure 1.0-1), and consists of four impoundments. The sequence of the four Lewis River impoundments upstream of the confluence of the Lewis and Columbia rivers is: Merwin, Yale, Swift No. 2, and Swift No.1. These four impoundments 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 impoundments. Combined, the Lewis River Projects have a generation capacity of approximately 606 megawatts.

On June 26, 2008, FERC issued Orders approving the Settlement Agreement (SA) and granting new licenses for the North Fork Lewis River Hydroelectric Projects to PacifiCorp and Cowlitz PUD. Among the conditions contained within the SA was a requirement for reintroducing anadromous salmonids and providing fish passage upstream of Merwin 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 SA for reintroduction are spring Chinook salmon (*Oncorhynchus tshawytscha)*, early-run (S-type) coho salmon (O. *kisutch)*, and winter steelhead (O. mykiss).

The SA 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. In April of 2019, the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), referred to collectively as the Services, issued preliminary decisions regarding future fish passage into Merwin and Yale reservoirs. More information on this decision can be found at: https://www.pacificorp.com/energy/hydro/lewis-river.html.

The Lewis River Aquatic Monitoring and Evaluation Plan (M&E Plan; PacifiCorp and Cowlitz PUD 2017) was developed as part of the SA to evaluate performance measures outlined in the SA. The primary focus of the M&E Plan is to provide methods for monitoring and evaluating the fish passage program. In accordance with the SA, the Utilities 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 (Section 9.1 of the SA). The original M&E Plan was finalized and approved by the ACC in June 2010. The first revision of the M&E Plan was completed in 2017, and was fully implemented that year (PacifiCorp and Cowlitz PUD 2017). The purpose of this report is to document results of the field assessments associated with implementation of the fish passage program in the existing M&E Plan during 2019.

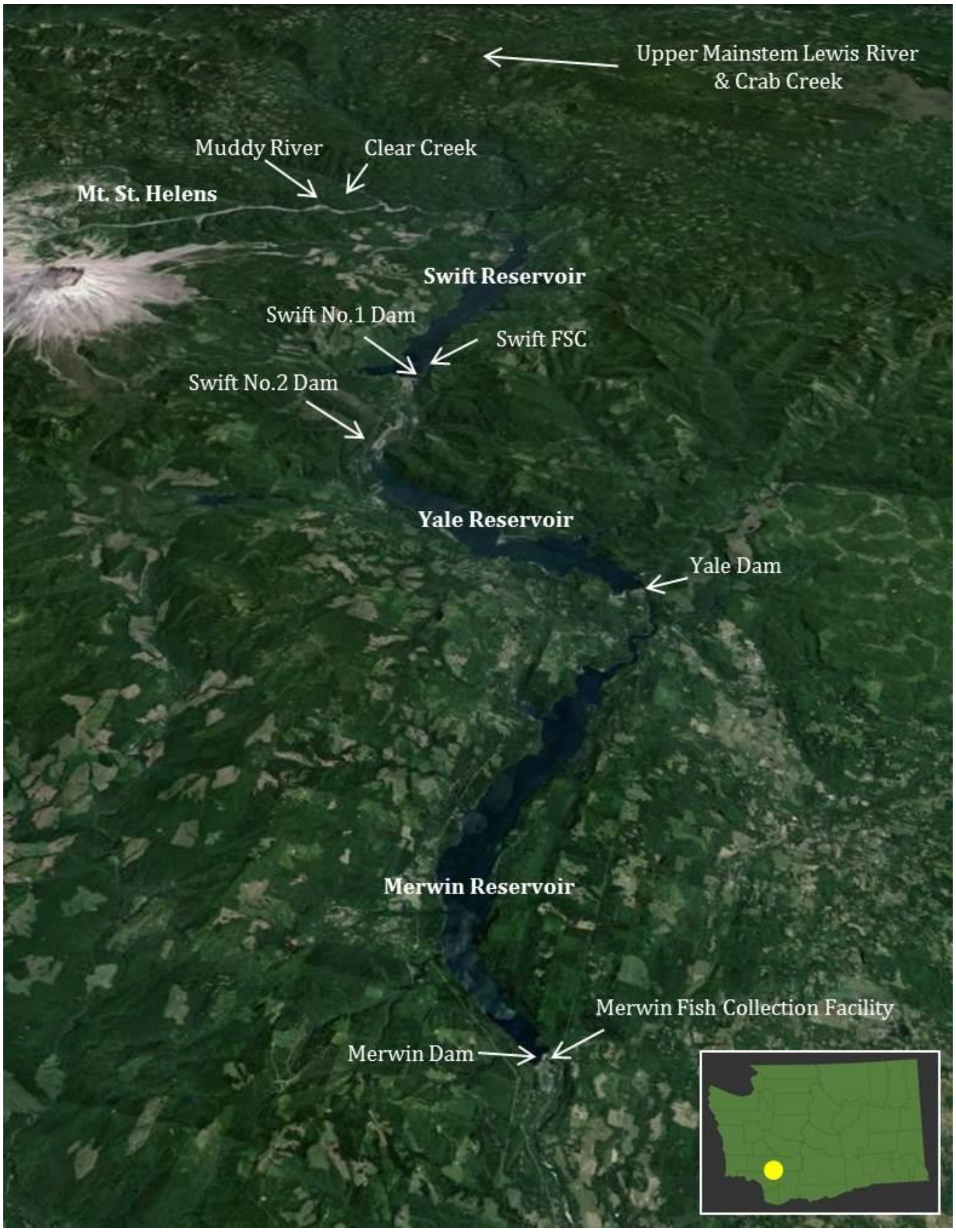

Figure 1.0-1. An overview of key features of the North Fork Lewis River Hydroelectric Project area located in southwest Washington.

Some noteworthy environmental conditions and procedural changes occurred, or continued to be implemented, in 2019. These are summarized below:

- *Minimum Flow Requirement Below Merwin Dam:* During August 2019, flows below the Merwin Project were released at a rate below minimum flow levels stipulated in the June 26, 2008 FERC licenses. This was in response to very low summer inflows, and was approved by the Lewis River Flow Coordination Committee. On average, annual flows below Merwin Dam were lower than the 10-year average (Figure 1.0-2).

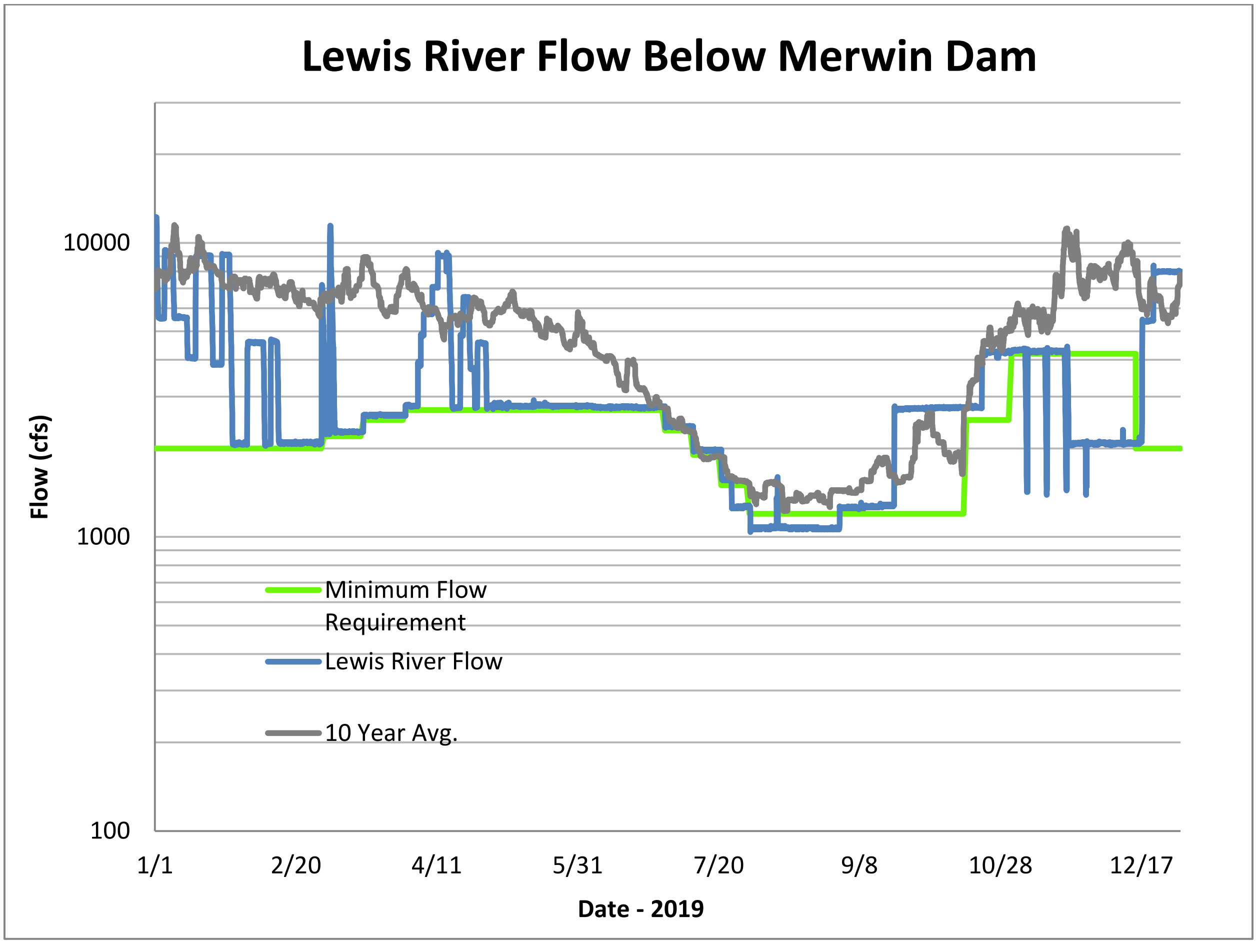

Figure 1.0-2. Lewis River flow below Merwin Dam as recorded by USGS gage (14220500 Ariel WA). Minimum flow requirements are also shown. The sharp 'dips' in flow during November are scheduled drawdowns associated with WDFW fall Chinook surveys.

- *Floating Surface Collector (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 surface temperatures reach approximately 18°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 Dam Adult Fish Facility 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 lift and conveyance system to remain operational seven days per week; however, daily sorting of fish only occurs Monday through Friday. These operational changes were also followed in 2019.

- *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. A detailed description of these modifications can be found in the Lewis River Fish Passage Program Annual Report for 2015 (PacifiCorp 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-run (Type – N) coho as an upstream supplementation species;

    - Extending the upstream transport schedule to include both early (Type – S) and late (Type – N) stocks of adult coho.

  At the September 2019 ACC meeting, adult coho release strategies were reviewed, and restored back to 9,000 adults to be transported upstream. The proportion of fish distributed between early- verses late-stock, and natural- verses hatchery-origin remained the same as outline in the 2019 Annual Hatchery and Supplementation Operating Plan.

- *Releases of Acclimation Fish Changed From Upstream Releases to Downstream Releases:* On May 31, 2018, the 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 be held 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 throughout the available upper basin habitat for spawning. As naïve hatchery spring Chinook adults transported above Swift Dam in 2017 and 2018 spawned widely across the available habitat (i.e., 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. It was recommended 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 the Lewis River Fish Passage Program 2018 Annual Report. The H&S subgroup recommended that beginning in 2019, all juvenile spring Chinook formally allocated to the upper basin release ponds will be fully integrated 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 available to be taken upstream as part of the reintroduction efforts. This increase in fish numbers would also help to increase sample sizes for spring Chinook as part of the ongoing H&S subgroup release strategy evaluation. This action was discussed and approved at the June 14, 2018 Lewis River ACC Meeting. These recommendations by the H&S subgroup were adopted and continued in 2019.

- *Acclimation Pond Decommissioning:* On December 5, 2017, PacifiCorp filed with FERC a request for Commission approval to decommission the juvenile fish acclimation pond facilities located along the Muddy River, Clear Creek and upper Lewis River near Crab Creek within the Gifford Pinchot National Forest. On January 4, 2018, the Commission responded with an order approving the December 5, 2017 request. The acclimation site located on the Muddy River was decommissioned from August through October of 2018. The acclimation sites located along Clear Creek and in the upper Lewis River near Crab Creek were both decommissioned from August through November 2019. All sites were restored to pre-construction condition. The final decommissioning report was filed with FERC on December 12, 2019 (a copy of the filing is provided in Appendix A).

- *Nutrient Enhancement Above Swift Dam:* The possibility of using surplus hatchery-reared adult coho carcasses for nutrient enhancement upstream of Swift Dam in fall 2019 was discussed at June 27, 2019 Lewis River Aquatic Technical Subgroup (ATS) Meeting. The general consensus was that if enough carcasses were available and there was staffing to help support the distribution of carcasses, this effort should be considered. The use of adult coho carcasses for nutrient enhancement above Swift Dam was approved by the Lewis River ACC at the July 11, 2019 meeting. The plan was to release the carcasses at three upper Lewis River sites: Muddy River bridge, Clear Creek bridge, and upper Lewis River bridge near Crab Creek. The plan was to release a total of approximately 2,800 carcasses spread evenly among sites from mid-October through the end of November. Both early- and late-run adult coho carcasses would be used. The final report summarizing the 2019 Nutrient Enhancement effort was provide to the Lewis River ACC at the December 12, 2019 meeting (a copy of the final report is provided as Appendix B).

2.0 PASSAGE FACILITIES

2.1 Swift Reservoir Floating Surface Collector

The Swift Reservoir 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 FSC 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 size (i.e., life-stage: fry, smolt, and adult) and then routes them to holding tanks for biological sampling and transport downstream[2]. The artificial stream channel is maintained at a capture velocity of approximately 7 feet per second (fps) with 600 cubic feet per second (cfs) attraction flow during normal operations (80 percent of full flow capacity).

[2] Following transport downstream, smolts are released into the Woodland Releases Ponds located near Woodland, Washington. Fish are held in these ponds for 24 hours before being allowed to volitionally enter the river.

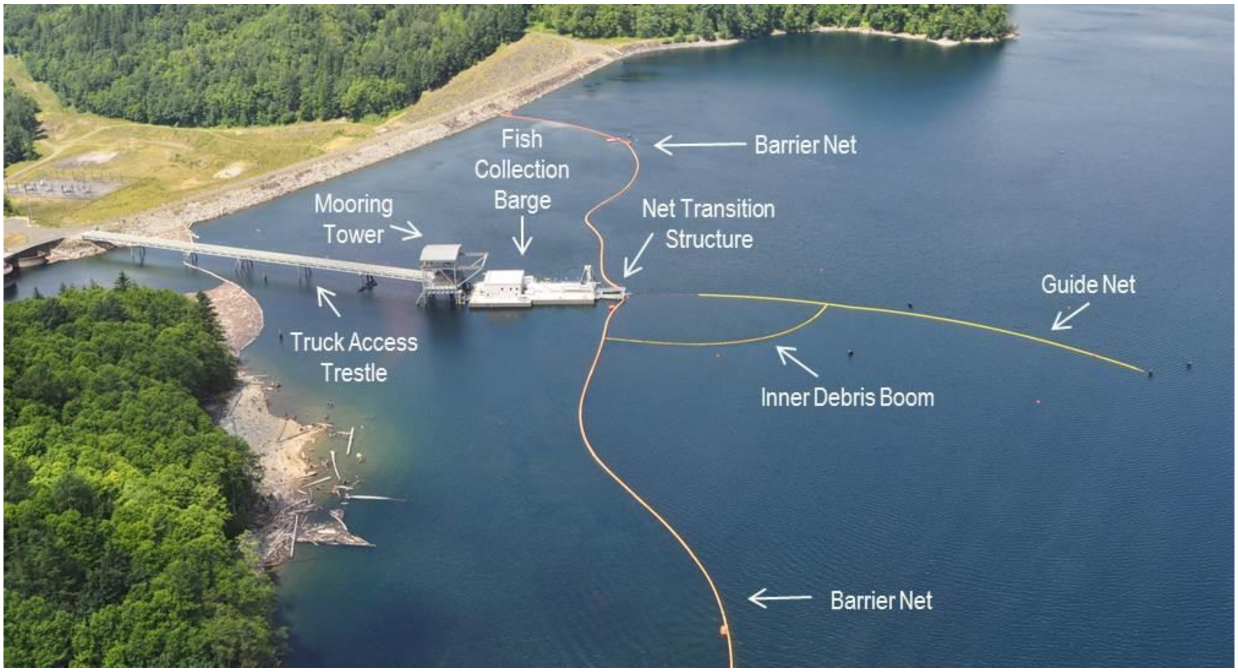

Figure 2.1-1. Aerial photo of the Swift Reservoir Floating Surface Collector.

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

The portion of the exclusion net 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

[3] 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.

In February 2019, the NTS was modified to increase water velocity (i.e., attraction flow) at the entrance. The entrance of the NTS is 30 feet wide by 37 feet deep (1,110 square feet). The floor of the NTS then slopes up to a depth of 12 feet at the connection with the FSC fish channel. A false floor was installed at a depth of 22 feet from the entrance of the FSC running horizontally downstream until connecting to the NTS floor at about half way down the flow-wise length of the NTS. In doing this the cross sectional area of the entrance was decreased from 1,110 square feet to 660 square feet. During the spring of 2019, the baffles of the dewatering screens in both the primary and secondary channels were re-tuned to operate under maximum attraction flow capabilities. This increased the FSC regular operating flow from 600 cfs to approximately 860 cfs. With the reduced area at the entrance of the NTS combined with high flow volume, the entrance water velocity at the FSC increased from 0.5 fps (feet per second) to approximately 1.3 fps. These changes were evaluated in spring 2019 to determine changes in fish behavior and collection efficiency (see Section 3.4 below).

The FSC operated 24-hours a day through 2019 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 2019.

Date	Reason For Outage
01/12/19-02/04/19	Modifications to Net Transition Structure
02/09/19-02/14/19	Snow loading and ice buildup
07/23/19-10/14/19	Summer maintenance period
12/06/19	Surge suppression installation
12/20/19-12/31/19	Access stairs and surge suppression installation

2.2 Merwin Dam 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 in 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 SA, 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
- Fish Lift and Conveyance System
- Sorting Facility

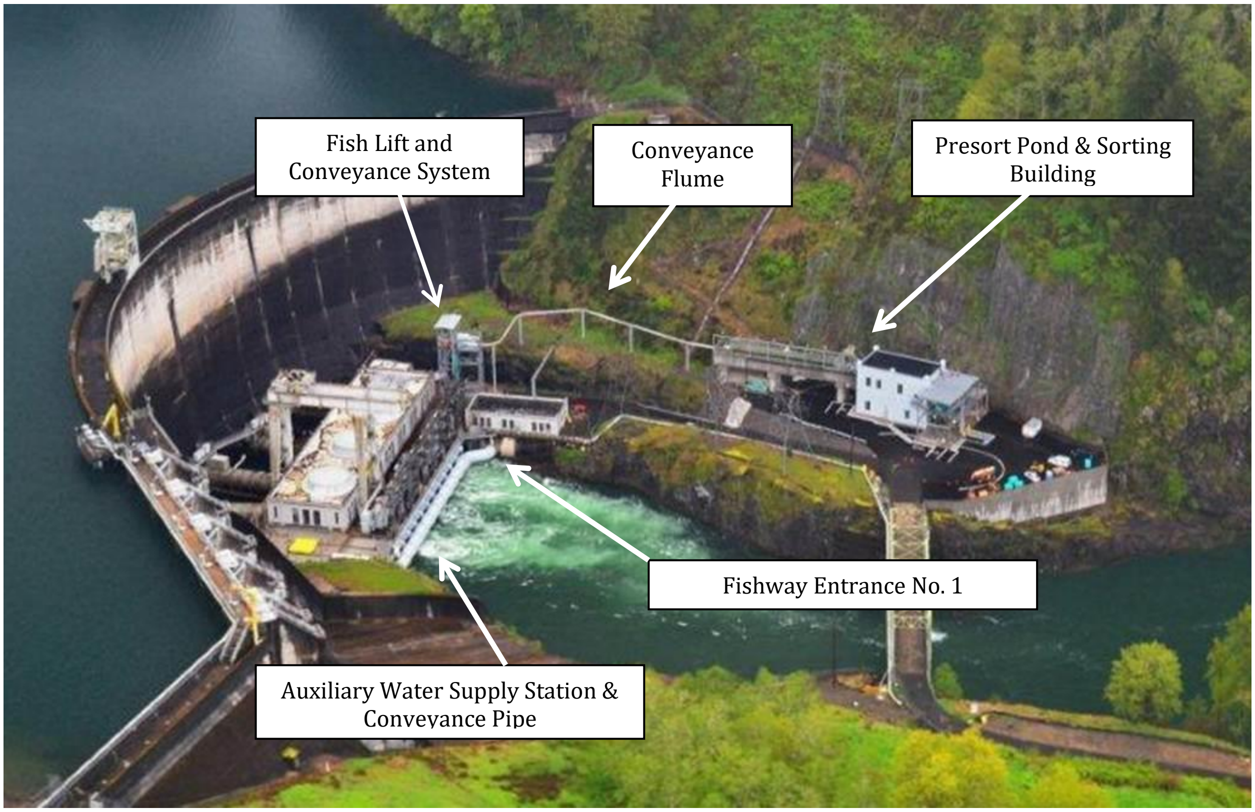

Figure 2.2-1. Merwin Dam Upstream Collection Facility.

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) (approximately 11 cfs) and the ladder water supply (LWS) system (approximately 19 cfs). The vertical slots allow the pool levels to self-regulate the water surface elevation. Depending on tailrace 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 2019 except during periods when it was necessary to shut the facility down due to facility modifications, scheduled maintenance, or emergency repairs (Table 2.2-1).

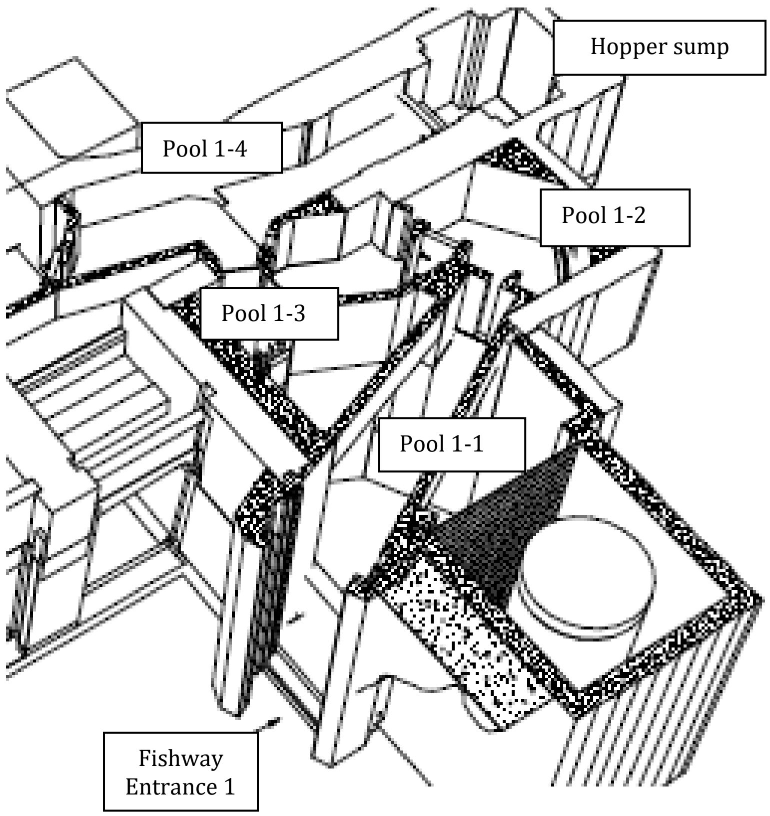

Figure 2.2-2. Merwin Dam fish ladder entrance and pool configuration.

Table 2.2-1. List of scheduled and unscheduled outages at the Merwin Fish Sorting Facility in 2019.

Outage Duration	Purpose for Outage
2/8/19-2/14/19	Maintenance outage
4/6/19-4/7/19 [a]	Broken limit switch
4/10/19 [a]	Broken limit switch
7/22/19 [a]	Broken limit switch actuator
7/25/19-8/6/19	Broken limit switch actuator, cable replacement, and damaged screen on attraction pump
8/23/19 [a]	Mechanical issues with crowder
10/12/19-11/03/19	Broken crowder assembly
12/5/19 [a]	Repairs on vertical crowder (presort pond)

[a] The fish ladder and fyke remained operational - only the fish lift and conveyance system was not operated.

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 FSC before volitional release into the lower Lewis River at approximately river mile 8.5.

The Woodland Release Pond Facility is comprised 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 are manually enumerated. 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 within 48 hours. Out-migrants exit through a fish transfer flume and outfall into the lower Lewis River.

The Woodland Release Ponds were operated in concurrence with the Swift FSC in 2019, with the exception of an unscheduled outage that occurred from May 16 through June 10, 2019. This unscheduled outage was due to unexpected repairs to one of the facility's two water supply pumps. During this period, out-migrating fish collect at the Swift FSC were released directly into the lower Lewis River at the Washington Department of Fish and Wildlife (WDFW) boat ramp on Pekin Ferry Rd. at approximately river mile 3.0.

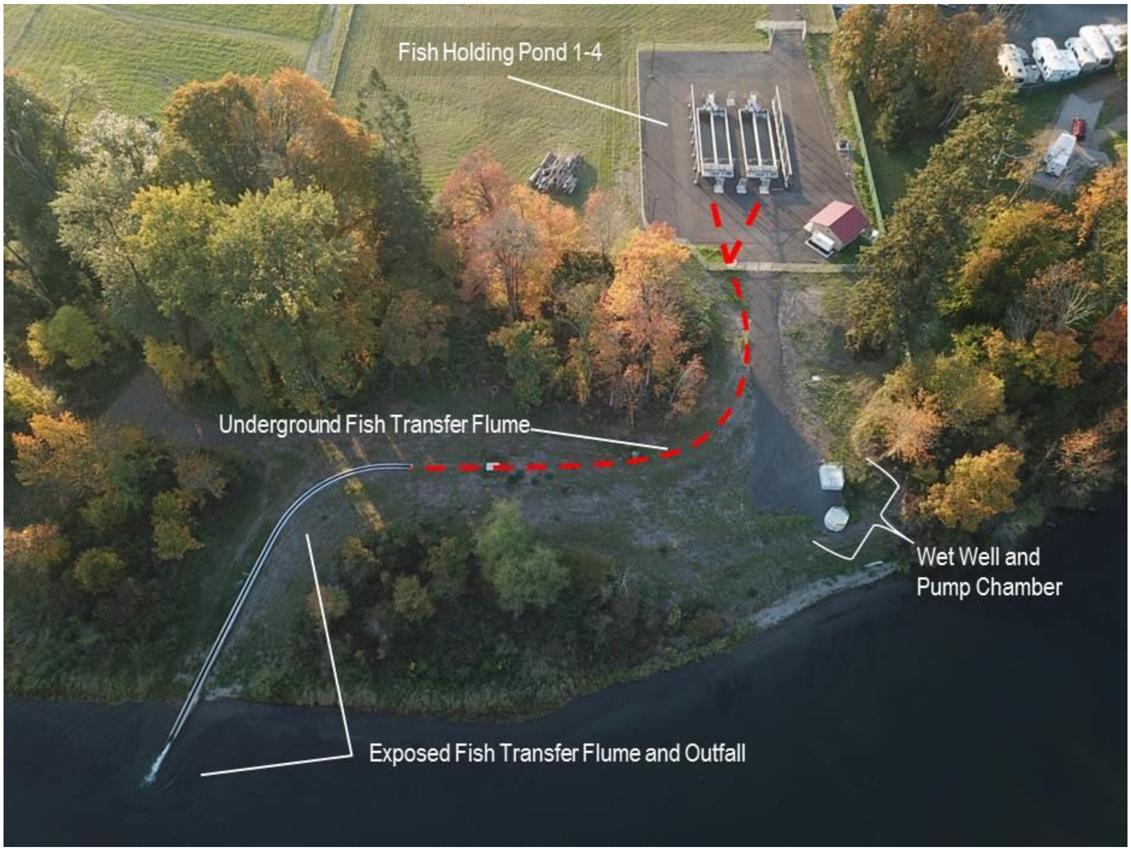

Figure 2.3-1. Aerial photo of the Woodland Release Ponds and associated infrastructure near Woodland, WA.

3.0 DOWNSTREAM COLLECTION AND PASSAGE METRICS

3.1 Number of Juveniles Entering Swift Reservoir

3.1.1 Overview/Methods

Developing an annual estimate of the total number of juveniles entering Swift Reservoir is required under Section 9.2.1 of the SA 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 due to unpredictable river and weather conditions (i.e., in the fall and late-winter). Additionally, these historical estimates do not include fish that enter Swift Reservoir from reservoir tributaries (e.g., S20, Swift, Drift creeks, etc.).

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 unsampled 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 Passive Interrogated Transmitter (PIT) tag data collected at the Swift 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 are to be calculated using the following formula for use of a single partial trap described in Volkhardt et al. (2007), in which the estimated number of unmarked fish migrating during discrete sample period *i* ($\hat{U}$), weekly or monthly, is dependent on actual recapture rates observed:

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

Where:

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

Discrete sample period variance:

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

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

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

Entire monitoring period variance:

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

95 percent Confidence Interval:

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

- In addition, total season variance and confidence intervals are also to 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 are also to 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) see Section 3.7 below). These data are also to be used to estimate the total number of juvenile migrants in Swift Reservoir using mark-recapture.

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 2019, 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 percent confidence interval will be calculated using Equation 3.1-5 above.

3.1.2 Results/Discussion

Objective 7 Task 7.1:

Field crews operated the Eagle Cliff 8-foot-diameter rotary screw trap (trap) from March 5, 2019 to July 19, 2019, and checked the trap on a daily basis. The trap was turned off (cone raised) due to heavy debris loads from April 7, 2019 to April 14, 2019; 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). The majority of juvenile coho (79 percent), Chinook (75 percent), and steelhead (61 percent) captured were less than 60 mm in fork length (FL).

A total of 1,492 coho, 135 Chinook, 229 rainbow/steelhead, and 53 cutthroat were marked and released upstream of the trap (as fish were available from trap captures) to estimate trap efficiency via mark-recapture (Table 3.1-1). Fish were marked with a PIT tag, alcian blue tattoo, or upper caudal fin clip. Only fish great than 60 mm FL were used for mark-recapture efficiency tests. Due to low capture rates, all salmonid species efficiency tests were combined to generate weekly trap efficiency estimates (Table 3.1-2). It is important to note that all Chinook captured in the screw trap in 2019 were of natural origin as no hatchery-raised spring Chinook acclimation juveniles have been planted above Swift Dam since August 11, 2017.

Capture timing of juvenile coho and Chinook tended to peak during mid-June (Figure 3.1-3). Differing from this were steelhead that remained rather constant from early-April through late-June (Figure 3.1-4). Total estimates of fish passing the trap during the trapping period and 95 percent confidence intervals were generated using the bootstrap methodology (Thidenga et al. 1994) (Table 3.1-3). 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 3.1-4). In total 144,514 coho, 14,414 naturally produced Chinook, 15,900 steelhead, and 1,050 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
Coho[a]	0	5,545	1,519	1,492	61
Chinook[b]	0	504	169	135	8
Rainbow/Steelhead	10	361	237	229	9
Cutthroat	NA	1	54	53	8
Bull Trout	NA	22	33	0	0
All Salmonids Combined		6,433	2,012	1,909	86

Species	Total
Dace	1
Lamprey	2
Sculpin	107
Sucker	5
Three-spine Stickleback	123

[a]In addition, 6 Coho mini-jacks were captured in the screw trap.
[b]In addition, 2 wild adult Steelhead were captured in the screw trap

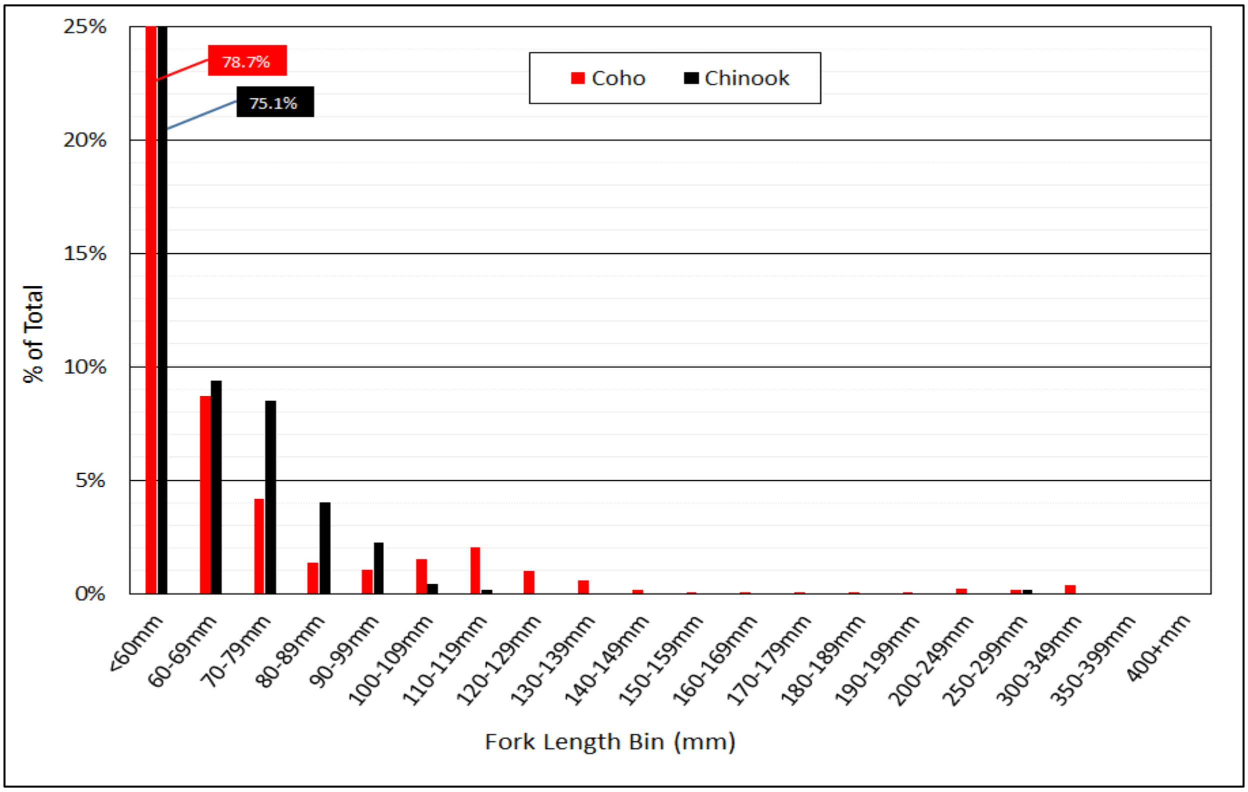

Figure 3.1-1. Length frequency distribution of juvenile salmon.

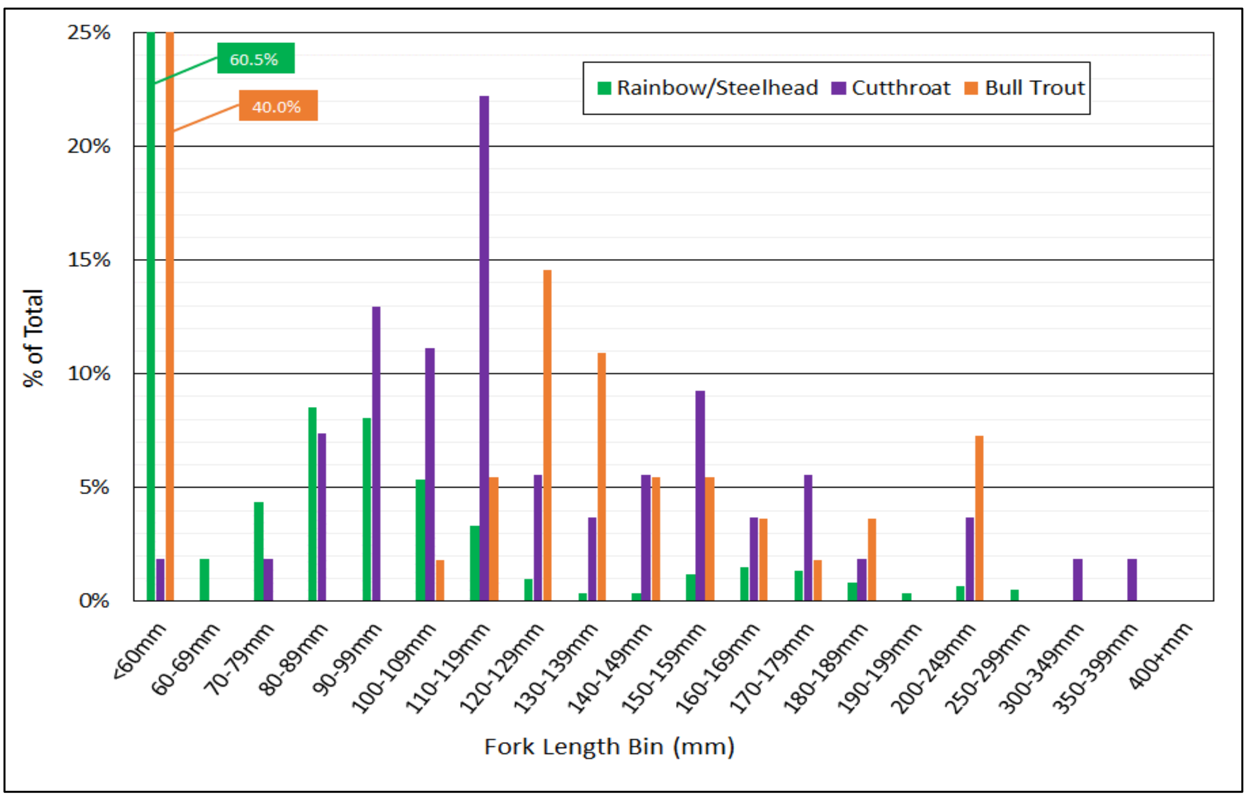

Figure 3.1-2. Length frequency of naturally produced trout/char.

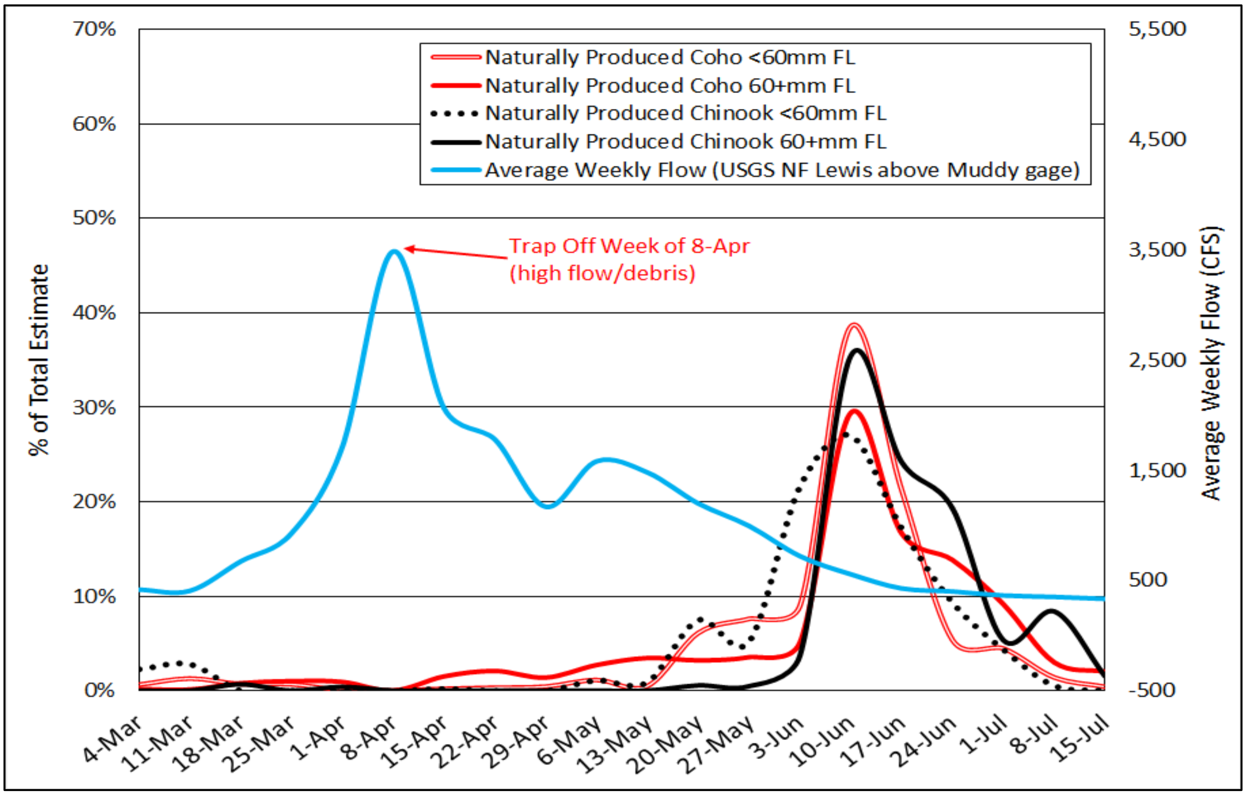

Figure 3.1-3. Naturally produced salmon migration timing.

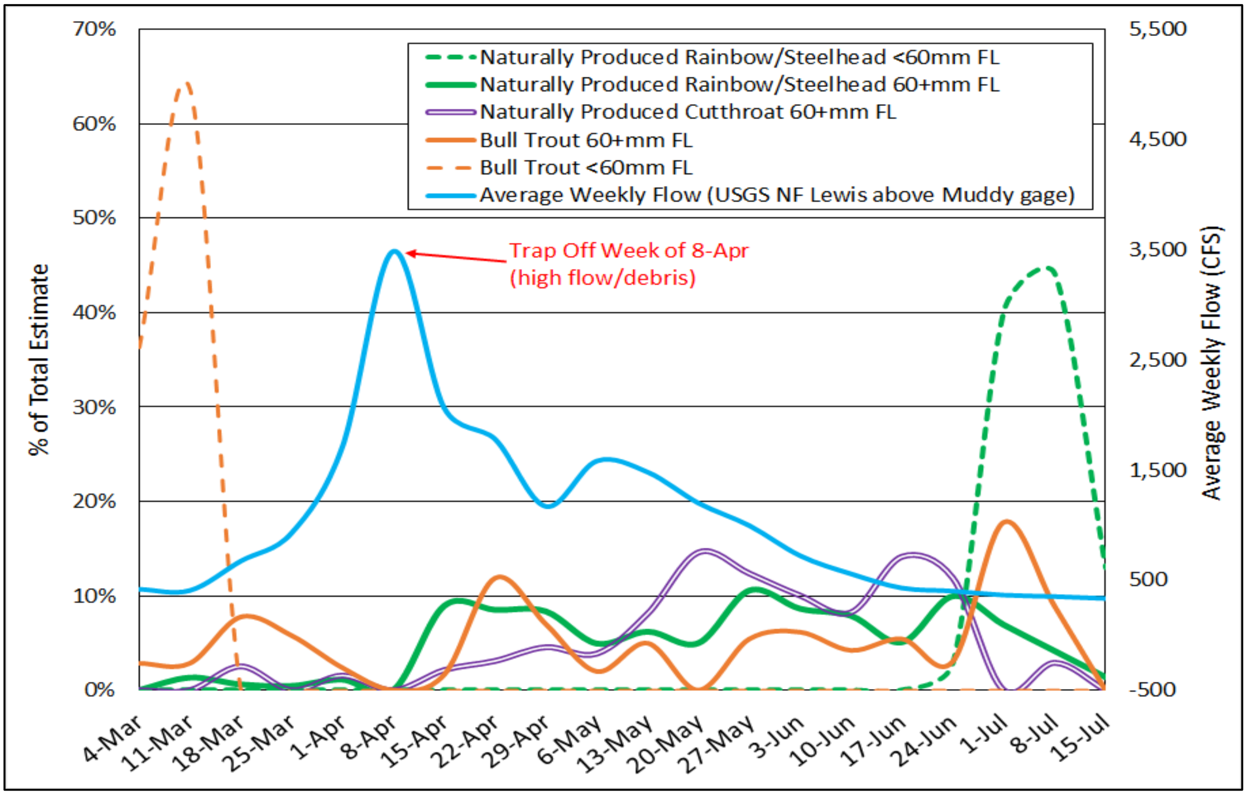

Figure 3.1-4. Naturally produced trout/char migration timing.

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
5-Mar	4	2	0	0.000	417	0.049[b]
11-Mar	6	5	0	0.000	405	0.049[b]
18-Mar	15	11	0	0.000	672	0.036[c]
25-Mar	20	18	0	0.000	927	0.048[d]
1-Apr	25	21	0	0.000	1,711	0.059[e]
8-Apr	trap not operated due to heavy debris			NA	3,486	NA
15-Apr	83	82	7	0.085	2,064	0.085[f]
22-Apr	73	68	4	0.059	1,780	0.059[f]
29-Apr	58	50	3	0.060	1,169	0.060[f]
6-May	87	85	6	0.071	1,581	0.071[f]
13-May	91	89	5	0.056	1,480	0.056[f]
20-May	67	66	1	0.015	1,199	0.044[g]
27-May	99	97	5	0.052	995	0.052[f]
3-Jun	113	110	5	0.045	721	0.045[f]
10-Jun	407	362	12	0.033	556	0.033[f]
17-Jun	375	369	19	0.051	428	0.051[f]
24-Jun	288	283	13	0.046	400	0.046[f]
1-Jul	122	118	3	0.025	364	0.03[h]
8-Jul	53	50	1	0.020	350	0.03[h]
15-Jul	26	23	2	0.087	332	0.03[h]
Total	2,012	1,909	86	0.045		0.049[i]

[a]USGS Gage 14216000 Lewis River Above Muddy River Near Cougar, WA.
[b]Combined efficiency measured during weeks with similar flow (weeks of 17-Jun and 24-Jun).
[c]Combined efficiency measured during weeks with similar flow (weeks of 03-Jun and 10-Jun).
[d]Combined efficiency measured during weeks with similar flow (weeks of 27-May and 03-Jun).
[e]Same as week of 22-Apr.
[f]No adjustment made to measured weekly efficiency.
[g]Combined efficiency measured during the weeks of 13-May through 27-May to address potential low sample size bias, which may underestimate trap efficiency.
[h]Combined efficiency measured during weeks with similar flow (weeks of 01-Jul through 15-Jul).
[i]Average adjusted season efficiency.

Table 3.1-3. Estimates of total naturally produced salmonids passing the Eagle Cliff trap (2019) by species (Bootstrap method).

Species	Capture Efficiency Applied[a]	Bootstrap Mean Total Estimate	95% CI +/-
Coho (≥60 mm FL)	0.049	31,071	6,258
Coho (<60 mm FL)	0.049	113,443	23,060
Chinook (≥60 mm FL)	0.042	4,120	1,170
Chinook (<60 mm FL)	0.050	10,294	2,387
Rainbow/Steelhead (≥60 mm FL)	0.049	4,855	1,168
Rainbow/Steelhead (<60 mm FL)	0.035	11,045	6,650
Cutthroat (≥60 mm FL)	0.052	1,050	348
Bull Trout (≥60 mm FL)	0.051	661	263
Bull Trout (<60 mm FL)	0.049	460	255

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

Table 3.1-4. Estimates of total naturally produced salmonids passing the Eagle Cliff trap (2019) by species (Sum of Discrete Interval Method).

Species	Total Estimate	95% CI +/-
Coho (≥60 mm FL)	32,005	7,159
Coho (<60 mm FL)	122,373	31,898
Chinook (≥60 mm FL)	3,799	1,108
Chinook (<60 mm FL)	10,595	2,923
Rainbow/Steelhead (≥60 mm FL)	4,051	962
Rainbow/Steelhead (<60 mm FL)	8,930	5,827
Cutthroat (≥60 mm FL)	1,053	404
Bull Trout (≥60 mm FL)	578	240
Bull Trout (<60 mm FL)	432	229

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 1,064 coho, 223 Chinook, 280 steelhead, and 51 cutthroat juveniles were tagged and released at the head of Swift Reservoir for analysis. Of these 651 coho, 55 Chinook, 202 steelhead, and 51 cutthroat were tagged and released at the Eagle Cliff screw trap. 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 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 2019. It was estimated that 213,531 coho, 44,186 Chinook, 16,314 steelhead, and 12,089 cutthroat juveniles entered Swift Reservoir during 2019 (Table 3.1-5). These estimates only consider fish parr size and greater (i.e., >60 mm FL), which could be PIT tagged. Comparing these estimates to the number of juveniles estimated to pass Eagle Cliff during screw trapping operations in 2019 suggests 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 3.1-5. Estimates of total naturally produced fish (adipose fin intact and ≥60 mm FL) entering Swift Reservoir during 2019 by species (bootstrap method).

Species	Tags Released	Tags Recaptured at FSC	Reservoir Survival (S_{RES}) Applied	Total untagged fish captured at FSC[a]	Bootstrap Mean Total Estimate	95% CI +/-
Coho	1,064	481	0.45	96,254	***213,531***	**14,472**
Chinook	223	56	0.25	10,887	***44,186***	**10,614**
Steelhead	280	23	0.08	3,013	***36,463***	**16,314**
Cutthroat	51	4	0.08	947	***12,089***	**21,603**

[i]Includes parr and smolt life-stages; no fry were PIT tagged.

3.2 Fish Numbers Collected at the FSC

3.2.1 Overview/Methods

Section 9.2.1(j) of the SA 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 original 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 current M&E Plan (2017); 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 percent and all fish collected are manually biosampled and enumerated. 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 current M&E Plan (2017), the daily subsample totals, as well as the associated variance estimators, are calculated by:

Total Number of Fish (subsampling period):

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

With associated variance estimator:

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

And 95 percent Confidence Interval:

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

Where,

T = total number of fish during the subsampling period
O = total number of fish during 100 percent 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 $\alpha/2$

Daily fish collection totals were manageable for the first four months of 2019 (January – April), and sample rates were set to 100 percent during this period. Record fish totals were collected during the spring out-migration period at the Swift FSC during 2019. Daily collection totals dramatically increased in late-May, and continued throughout the month of June. Sample rates were adjusted to between 10 to 25 percent during the peak of the outmigration. Subsampling occurred on 106 days of operation; from April 11 through July 7, 2019, and again from October 22 through November 4, 2019. For these periods, 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 standard error.

3.2.2 Results/Discussion

A total of 118,612 (95 percent confidence interval range: 88,961 to 148,263) salmonids were captured by the FSC in 2019 (Table 3.2-1). Of these fish, approximately 111,702 were transported and released downstream of Merwin Dam (Table 3.2-2). Juvenile coho accounted for the highest proportion of the overall estimated catch (83.5 percent), followed by Chinook (9.2 percent), steelhead (2.5 percent), and coastal cutthroat trout (0.8 percent). A total 1,413 hatchery rainbow trout and 5 bull trout were also collected in 2019 and returned to Swift Reservoir. An additional 2,992 hatchery rainbow trout were collected and passed downstream of Merwin Dam during the spring subsample collection period (April-July). All five bull trout captured in 2019 were collected when 100 percent of the fish were being directed to the subsample tank (i.e., not subsampling). No bull trout appeared in the sampling tank during the spring subsampling period; however it is possible that bull trout may have entered the general population tank and were subsequently transported downstream undetected.

Table 3.2-1. Estimated monthly and annual totals of all salmonids collected at the FSC in 2019.

Month	Coho				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	11	214	366	38	0	0	16	0	0	2	0	0	0	4	0	0	0	**651**
February	20	32	99	0	0	8	52	0	1	1	0	0	0	4	0	0	3	**220**
March	401	135	111	0	3	40	108	1	0	4	0	0	0	13	0	0	13	**829**
April	1,832	172	4,113	0	14	39	557	0	20	203	17	7	0	103	10	0	206	**7,276**
May	432	694	54,662	0	12	230	2,511	0	24	2,297	6	30	0	467	6	2	601	**61,968**
June	60	1,111	29,432	0	28	1,825	211	2	9	330	0	13	0	188	26	0	3,579	**36,814**
July	10	414	1,030	0	7	425	143	4	2	11	0	4	0	27	0	0	2	**2,079**
August	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
September	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
October	8	1357	1,694	28	0	193	4043	0	3	87	0	6	0	64	0	1	1	**7,485**
November	16	361	228	36	0	74	338	1	4	12	0	2	1	29	1	2	0	**1,105**
December	2	31	9	36	0	0	74	0	0	3	0	2	0	4	0	0	0	**161**
Annual Total	2,792	4,521	91,744	138	64	2,834	8,053	8	63	2,950	23	64	1	903	44	5	4,405	**118,612**

Table 3.2-2. Estimated annual totals of salmonids transported downstream in 2019.

Coho				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	
2,734	4,510	89,573	0	64	2,828	7,994	0	8	63	2,941	0	47	1	895	44	0	2,992	111,702

Table 3.2-3. Estimated annual totals of salmonids and life stage collected by the FSC in 2019.

Species/Lifestage	Estimated Number Collected	Total Error (95% CI)	Collection Range at 95% CI
Coho Fry	2,734	68	2,724-2,860
Coho Parr	4,510	877	3,644-5,398
Coho Smolt	91,744	22869	68,875-114,613
Coho Adult	138	0	138
Chinook Fry	64	0	64
Chinook Parr	2,834	502	2,332-3,336
Chinook Smolt	8,053	2,466	5,587-10,520
Steelhead Fry	8	0	8
Steelhead Parr	63	23	40-86
Steelhead Smolt	2,950	1,049	1,901-3,999
Steelhead Adult	23	0	23
Steelhead Kelt	64	0	64
Cutthroat Fry	1	0	1
Cutthroat <13 in	903	351	552-1,254
Cutthroat >13 in	44	36	8-81
Bull Trout	5	0	5
Rainbow Trout	4405	1,408	2,997-5,813
Total	**118,612**	**29,651**	**88,961-148,263**

3.3 Juvenile Migration Timing

3.3.1 Overview/Methods

In accordance with Section 9.2.1(a) of the SA, 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 current M&E Plan (2017), 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 FL to describe, temporally, the size (or life-stage) of fish entering the FSC. Size distributions for coho, 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 from mid-July through early-October as the FSC was off for annual summer maintenance.

3.3.2 Results/Discussion

With the exception of Chinook smolts, the run timing in 2019 followed a normal frequency distribution, with peak migration occurring in early June. The late-fall migration component was larger in total number than previous years, but made up a relatively small portion of the overall outmigration total in 2019. For coho, steelhead, and cutthroat trout, the most out-migration occurred between May 1st and June 30th. Within this time frame, 87.6 percent of the steelhead, 87.2 percent of the coho, and 72.5 percent of the cutthroat were collected relative to the total annual catch (Figures 3.3-1 through 3.3-12). Juvenile Chinook demonstrated a bimodal distribution run-timing curve, with approximately 49.6 percent emigrating between April 1st and June 30th, and 44.2 percent emigrating between October 15 and November 30, 2019

Coho Size Distributions

An asymmetrical bimodal size distribution was observed for juvenile coho collected at the FSC throughout the first quarter of the year (Figure 3.3-11). During the months of January-March, larger (>300 mm) coho smolts composed the majority of the catch, with a smaller proportion of the catch being composed of fry. 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 (>85 percent) 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 (81.7 percent) had lengths of less than 120 mm (Figure 3.3-11).

Chinook Size Distributions

All juvenile Chinook collected in 2019 represented fish naturally produced in the upper basin from adult spring Chinook transported upstream; no juveniles from the previous acclimation program were collected. Juvenile Chinook lengths observed in January-March demonstrated a fairly normal distribution pattern distributed about the mean (195 mm) (Figure 3.3-12). These fish were likely the progeny of spring Chinook adults released at Eagle Cliff in 2017. An asymmetrical, bimodal size distribution was observed for juvenile Chinook out-migrants during the spring (April-July), with a larger proportion (>80 percent) being made up of fish <130 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 2018.

Steelhead Size Distributions

Juvenile steelhead size distributions observed in 2019 were similar to those seen in previous years. The mean FL for steelhead captured in 2019 was 200 mm with the majority (>92 percent) having FLs that were >120 mm (Figure 3.3-13). During the peak spring-time migration period (April – June), the mean steelhead FL 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). Overall, fewer steelhead smolts were observed in 2019 than in 2017 and 2018, particularly for small fish (< 200 mm).

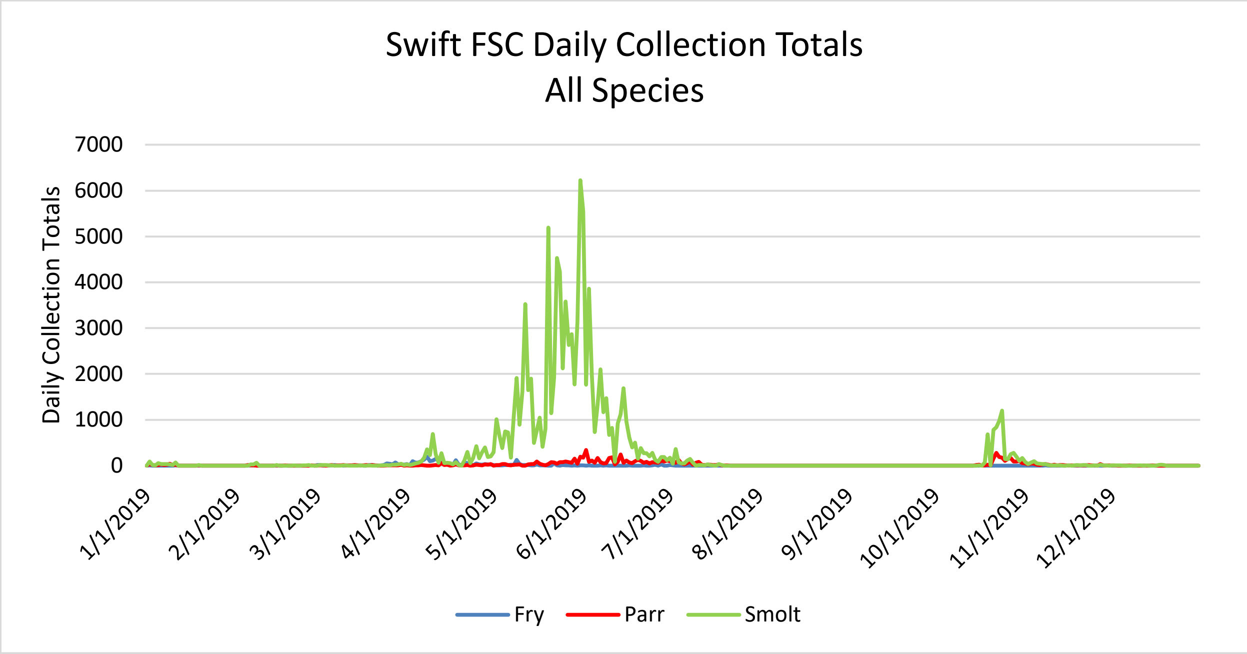

Figure 3.3-1. Estimated daily collection totals for all species at Swift FSC.

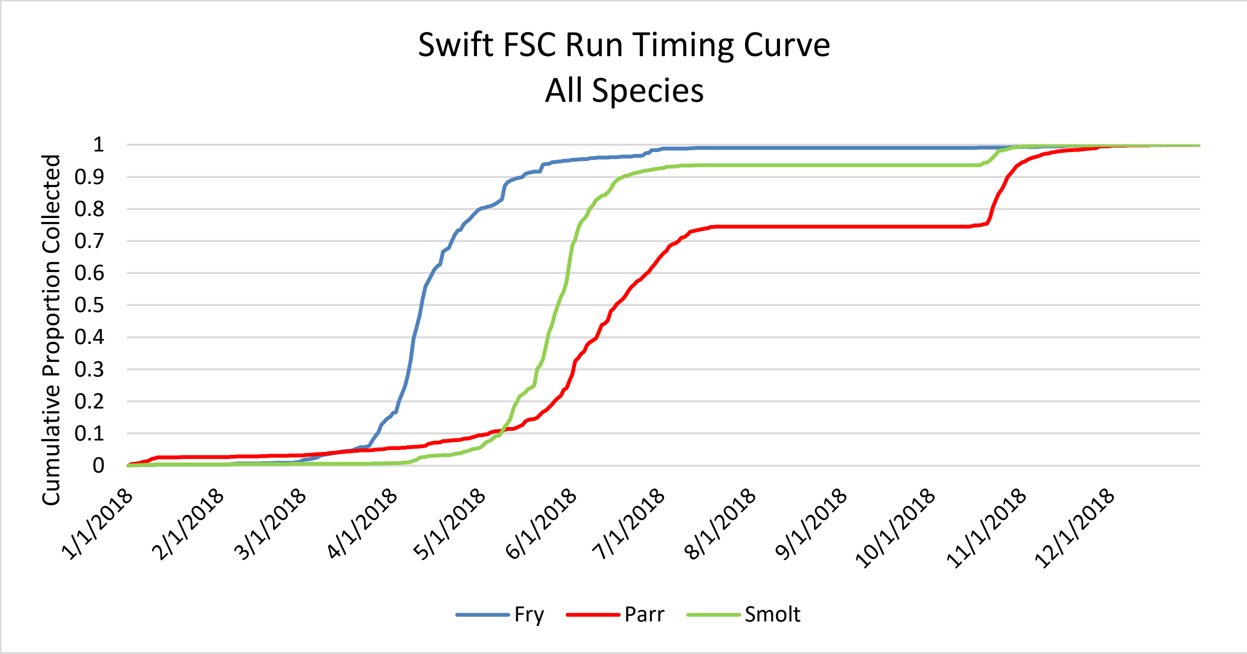

Figure 3.3-2. Cumulative migration timing among all species at Swift FSC.

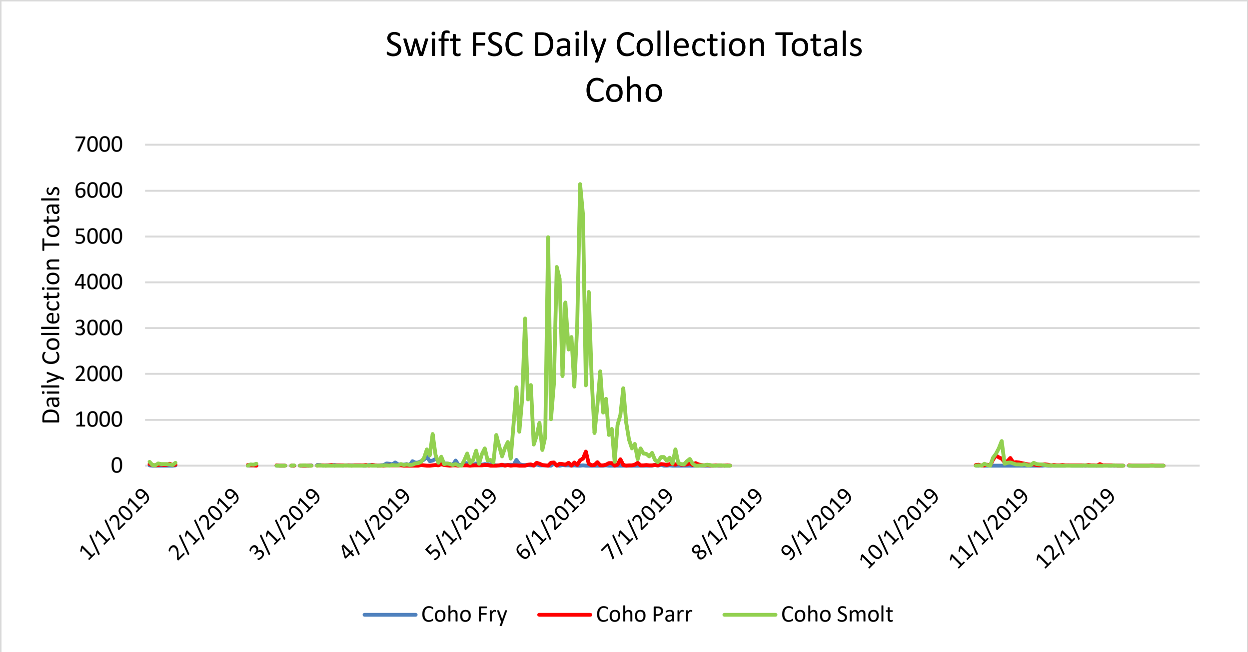

Figure 3.3-3. Estimated daily collection totals of juvenile coho at Swift FSC.

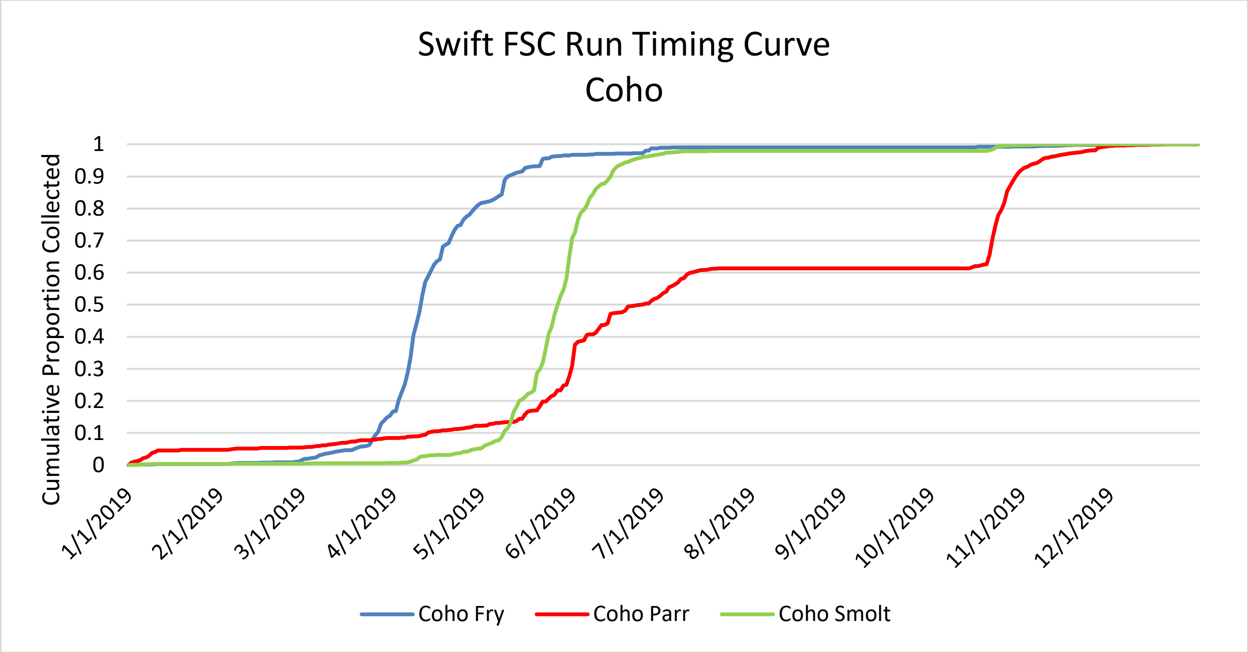

Figure 3.3-4. Cumulative migration timing of juvenile coho at Swift FSC.

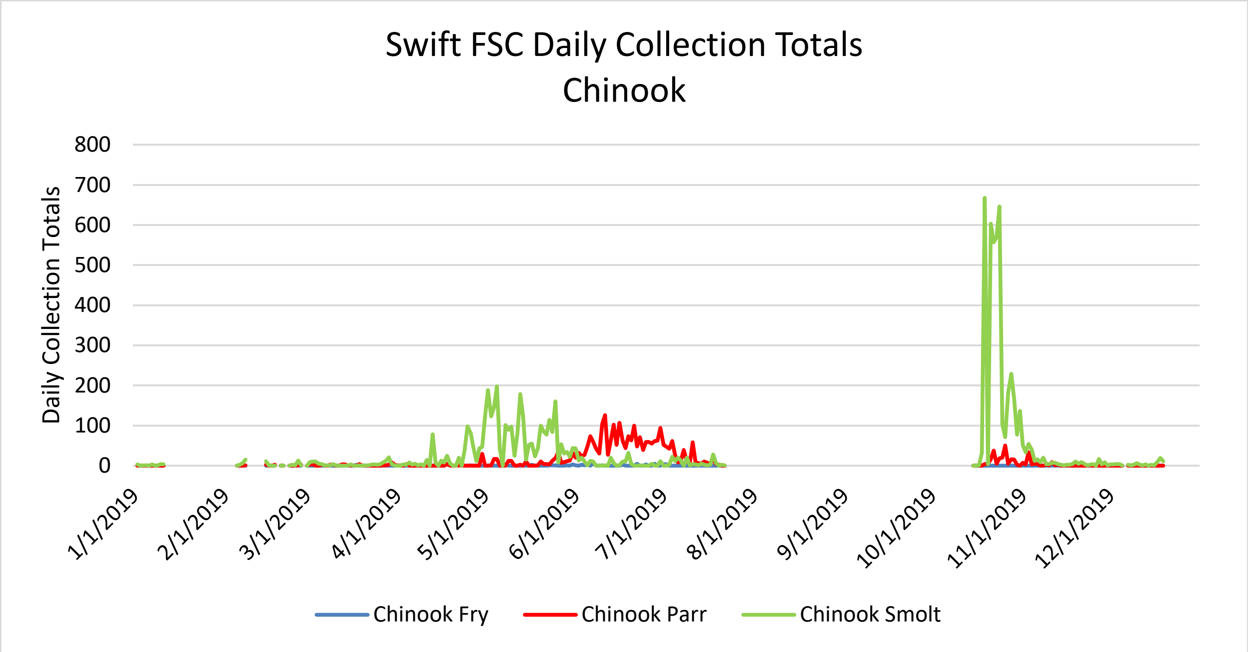

Figure 3.3-5. Estimated daily collection totals of juvenile Chinook at Swift FSC.

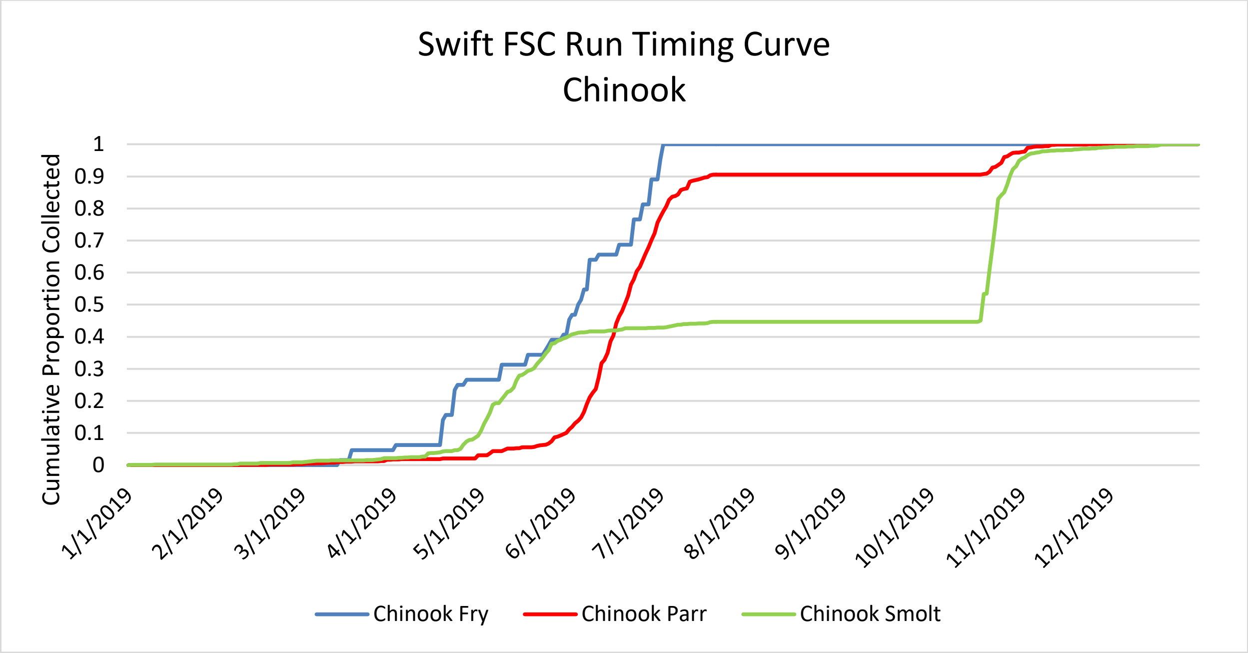

Figure 3.3-6. Cumulative migration timing of juvenile Chinook at Swift FSC.

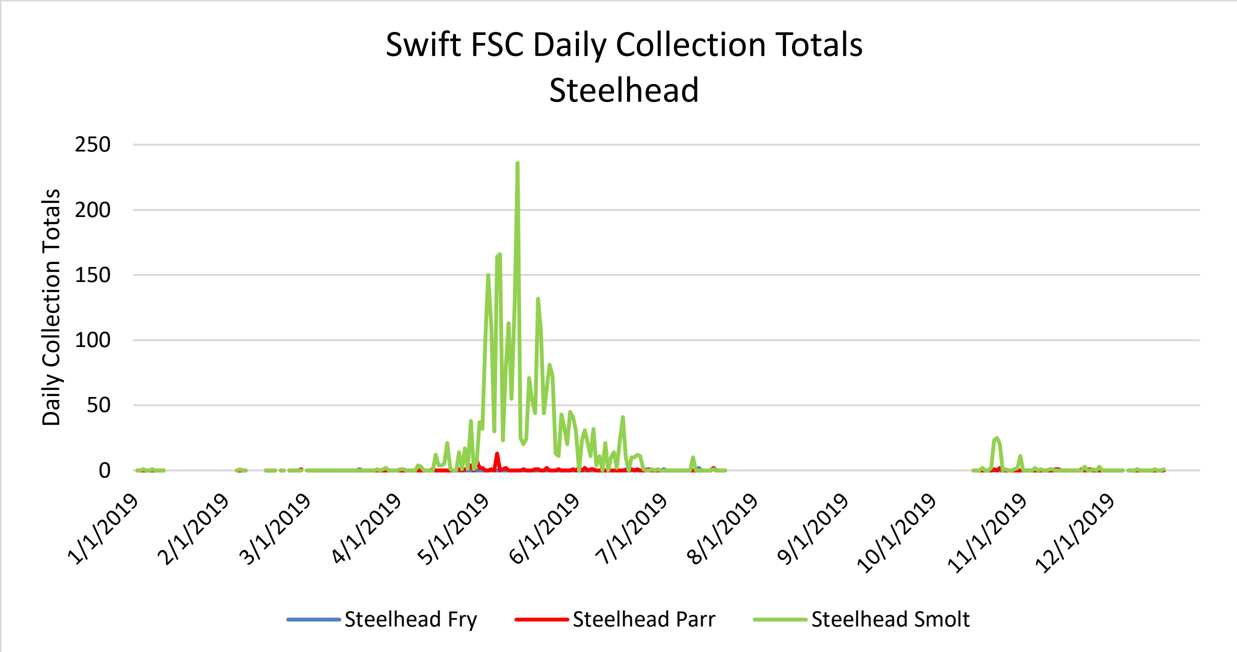

Figure 3.3-7. Estimated daily collection totals of juvenile steelhead at Swift FSC.

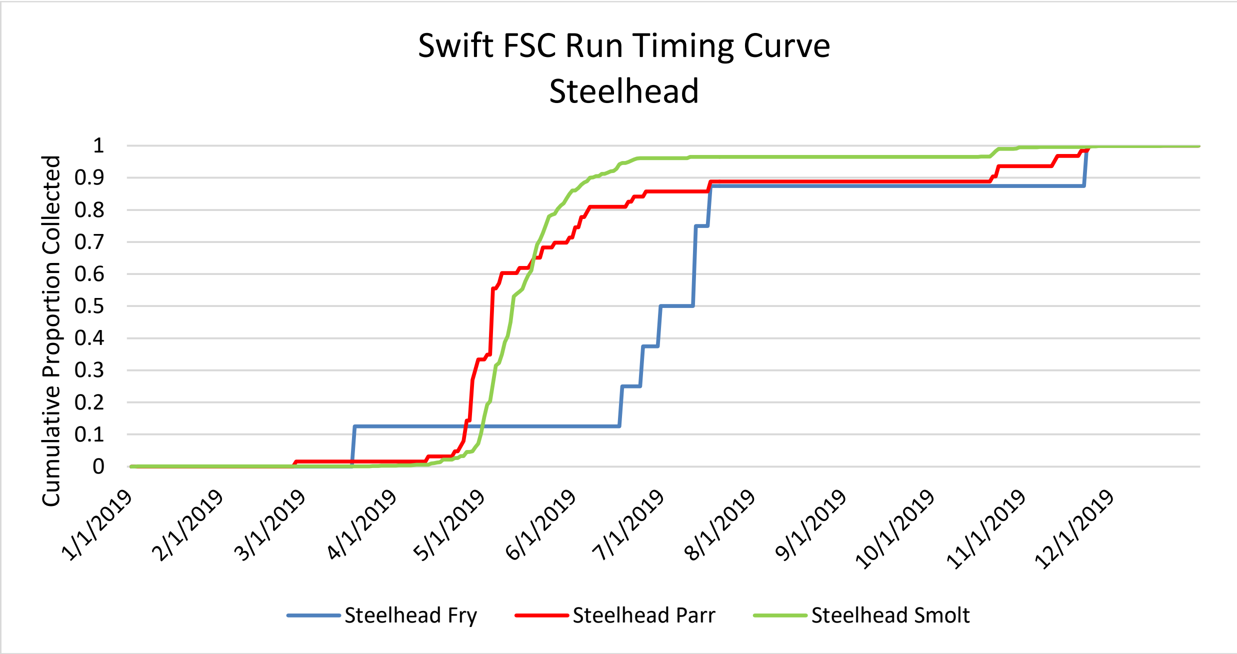

Figure 3.3-8. Cumulative run timing of juvenile steelhead at Swift FSC.

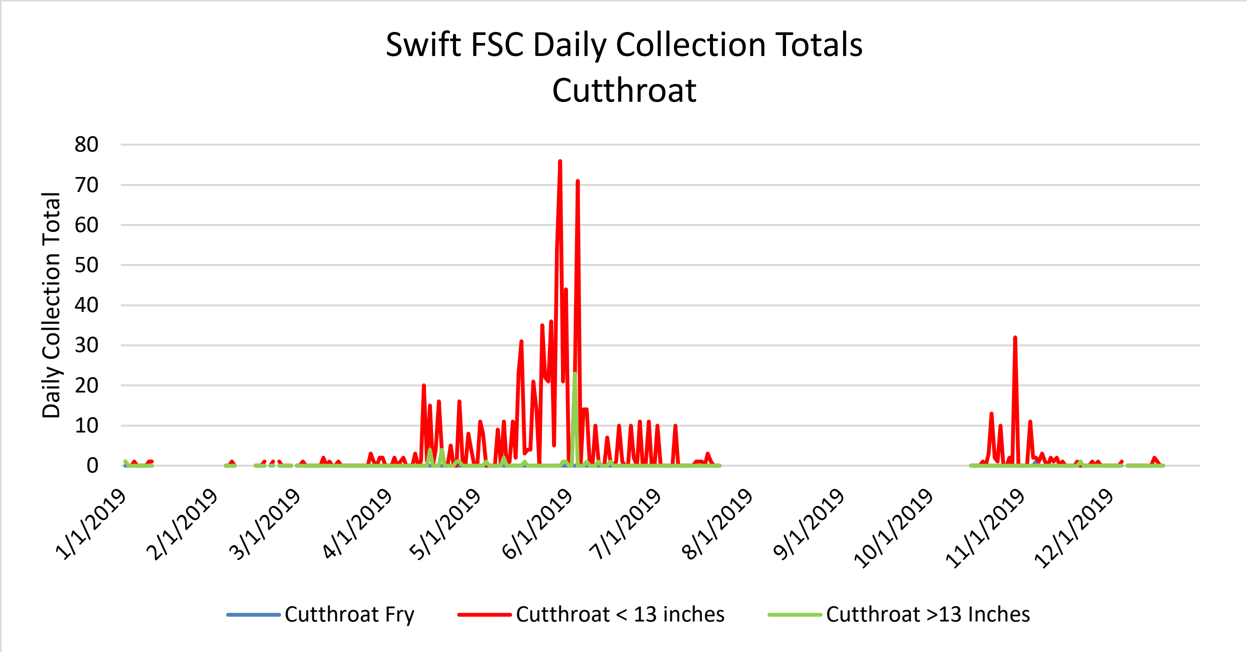

Figure 3.3-9. Estimated daily collection totals of juvenile cutthroat trout at Swift FSC.

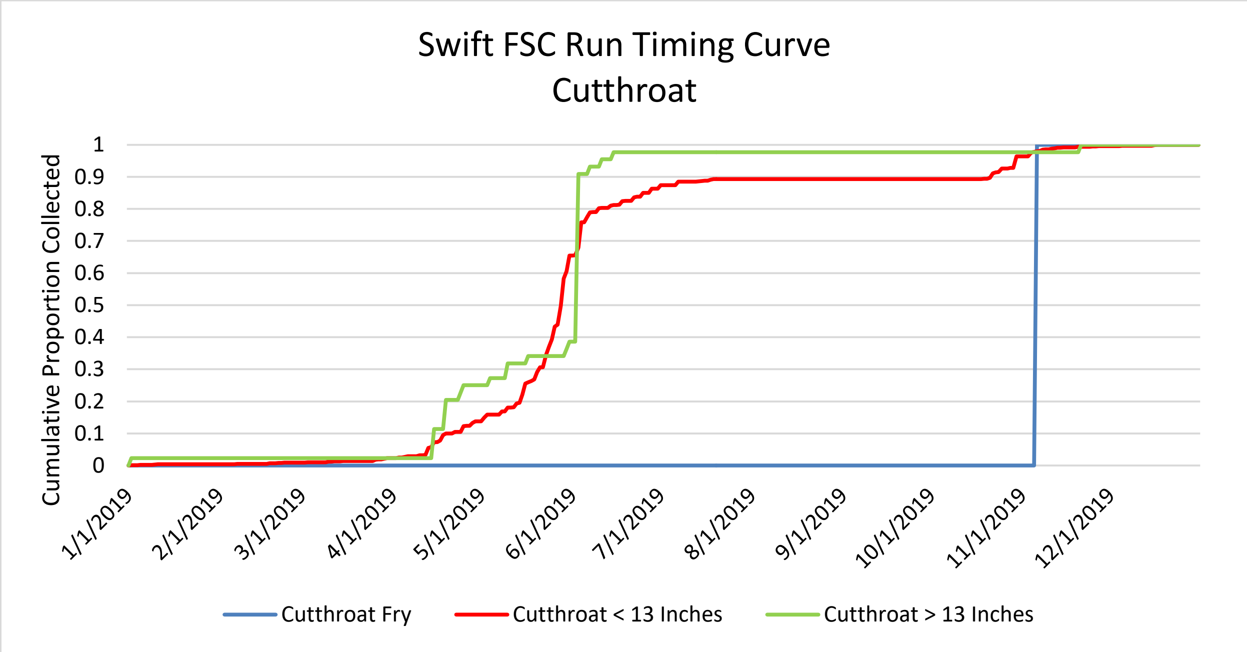

Figure 3.3-10. Cumulative run timing of juvenile cutthroat trout at Swift FSC.

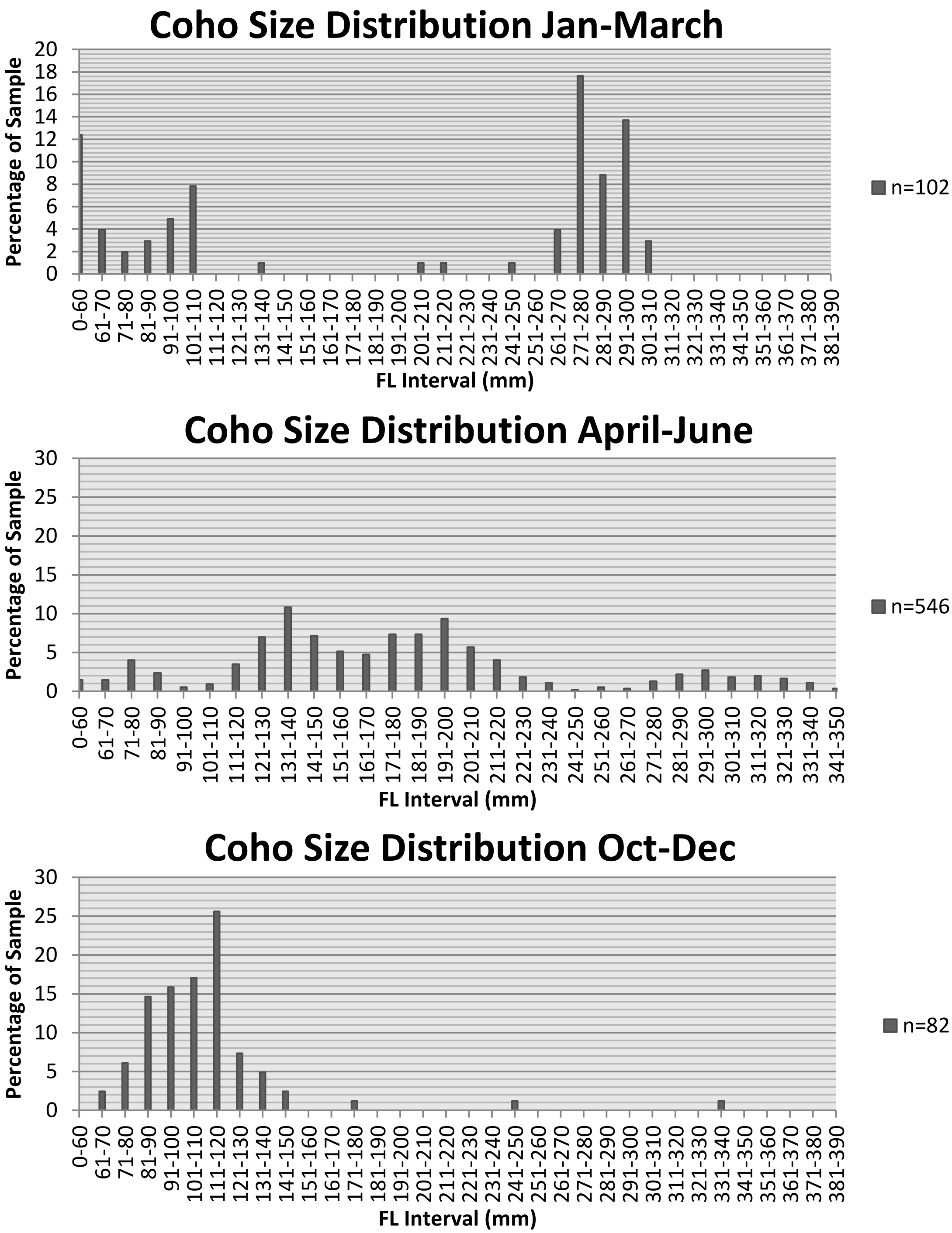

Figure 3.3-11. Size distribution of coho migrants collected at the Swift FSC in 2019.

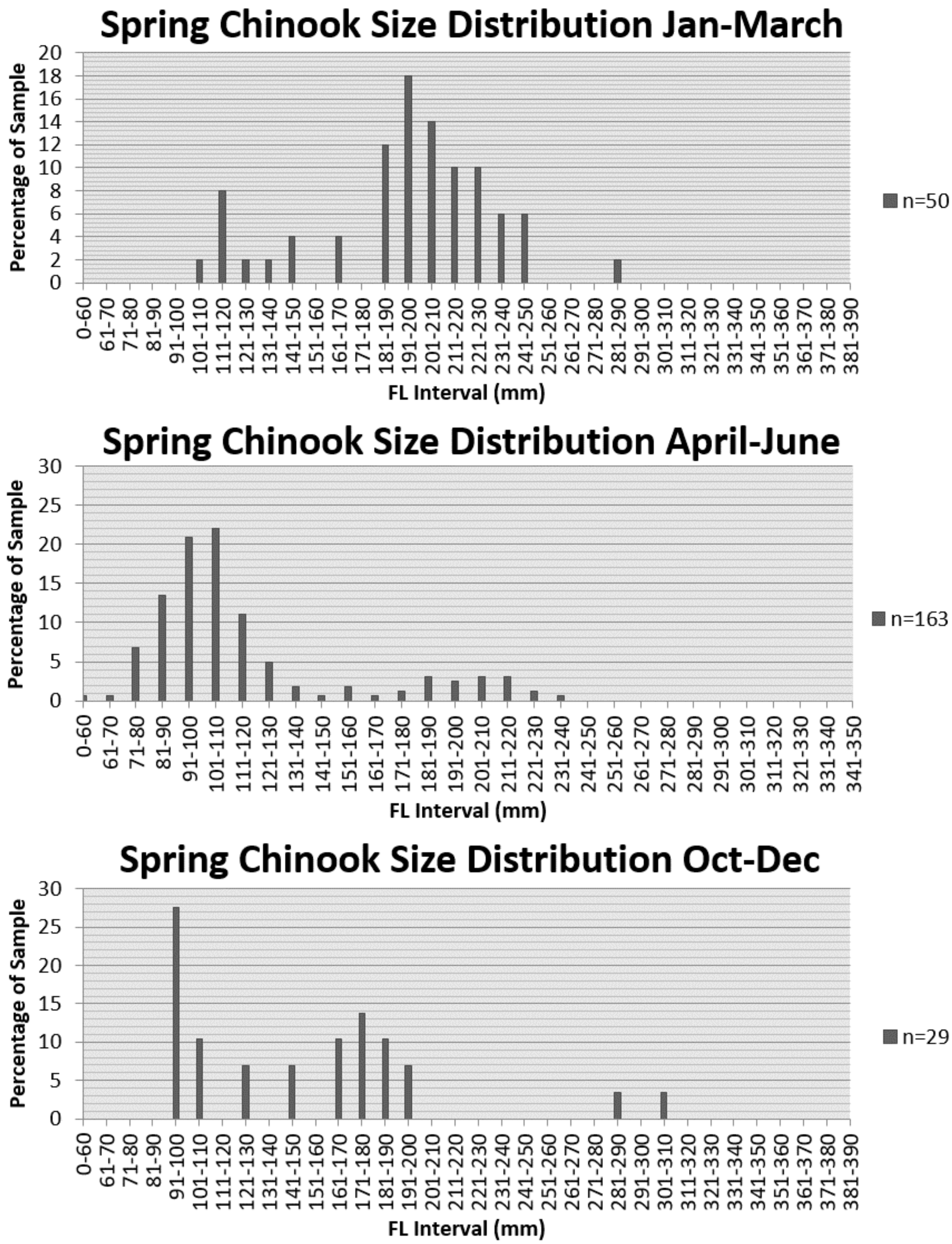

Figure 3.3-12. Size distribution of Chinook migrants collected at the Swift FSC in 2019.

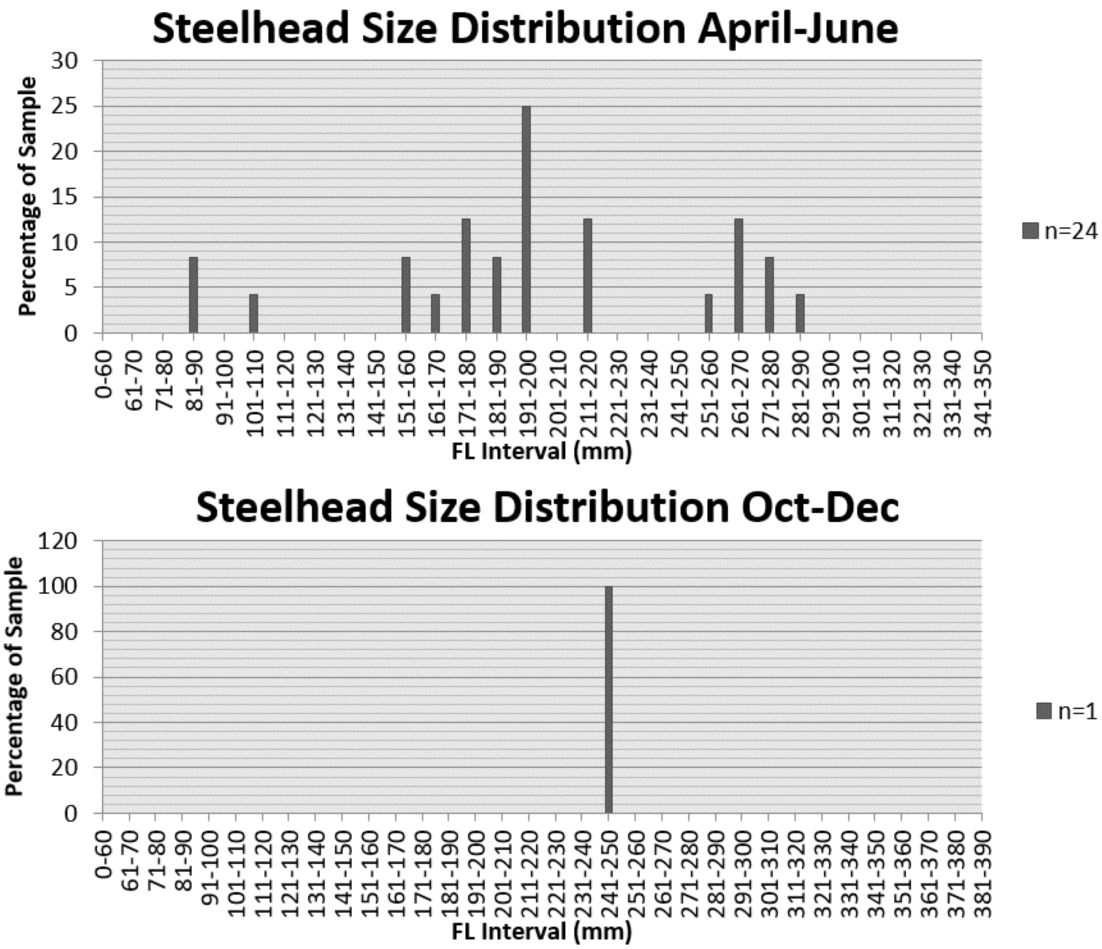

Figure 3.3-13. Size distribution of steelhead migrants collected at the Swift FSC in 2019. *Note- no steelhead measurements were taken during the Jan-March sampling period.

3.4 FSC Collection Efficiency

3.4.1 Overview/Methods

The use of biotelemetry to measure collection efficiency (P_{CE}) of juvenile salmonids at the FSC was further used in spring 2019. This evaluation was in accordance with Section 9.2.1(c) of the SA and based on findings and recommendations from the 2013 pilot study (Courter et al. 2013), 2014 evaluation (Stroud et. al 2014), 2015 evaluation (Reynolds et.al 2015), 2016 evaluation (Caldwell et. al 2017), 2017 evaluation (Anchor QEA 2018), and 2018 evaluation (PacifiCorp 2019), which is outlined in the Lewis River Fish Passage Program 2018 Annual Report. Objective 2 of the current M&E Plan (2017) defines P_{CE} as the percentage of juvenile salmonids emigrating from Swift Reservoir that is available for collection and that is actually collected. A juvenile that is available for collection is one that is detected within the zone of influence (ZOI); the area roughly 150 feet in radius immediately outside the NTS that was thought to be influenced by flow entering the FSC. A performance standard of 95 percent or greater for out-migrating smolts[4] was agreed upon for P_{CE}.

The primary goals of the 2019 Swift Reservoir out-migration study were: 1) determine collection efficiency for juvenile coho, spring Chinook, and steelhead smolts at the FSC; 2) continue to characterize the behavior of out-migrating smolts once they entered the Swift Reservoir forebay and as they interface with the FSC guide net and NTS; and 3) evaluate the effect of the modifications made to the NTS in spring 2019 to increase attraction velocity. More detail of the NTS modifications can be found in Section 2.1 of this report.

The specific study objectives of the 2019 FSC collection efficiency evaluation were to:

1. Estimate the proportion and transit time of downstream migrants released at the head of Swift Reservoir that arrive in the forebay of Swift Dam;

2. Estimate encounter rate (P_{ENC}), the proportion of downstream migrants that enter the FSC forebay and are detected in the FSC flow net attraction area immediately outside the Swift FSC, defined as the zone of influence ZOI;

3. Estimate entrance efficiency (P_{ENT}), the proportion of downstream migrants that enter the zone of influence and enter the FSC attraction channel;

4. Estimate P_{CE}, the proportion of downstream migrants that enter the ZOI and successfully pass into the FSC and are captured;

5. Estimate collection efficiency (P_{RET}), the proportion of downstream migrants that enter the collection channel and successfully pass into the FSC and are captured;

6. Describe the behavior of downstream migrants in the forebay of Swift Reservoir, specifically in the relation to the guide net, ZOI, and entrance of the FSC;

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

3.4.2 Result/Discussion

A detailed report describing the methods and results of the 2019 effort can be found in Appendix C. A brief summary of this report is provided below.

A total of 525 fish were dual PIT and acoustic tagged and released upstream of FSC between March 26 and June 26, 2019, to measure system performance and monitor fish behavior. At total of 155 Chinook, 300 coho, and 70 steelhead juveniles were tagged (Table 3.4-1). All study fish were released near Eagle Cliff at the head of Swift Reservoir. Although it was estimated that approximately 26 percent of the acoustic tags used in the study failed to activate prior to release, the remaining active tags were sufficient to provide a meaningful comparison to results from past studies. Metrics for transition probabilities downstream of the Swift Dam forebay were unimpacted and enabled accurate estimation of the rate of reservoir passage (P_{RES}).

In 2019, collection efficiency (P_{CE}) was estimated to be 51 percent for Chinook and 64 percent for coho, which were the highest recapture rates for those species of any study year to date. Collection efficiency for steelhead was estimated to be 27 percent, which was marginally higher than steelhead P_{CE} observed in previous years. However, PIT tag-only studies conducted in 2018 suggested that steelhead P_{CE} was significantly higher than in 2019. P_{RES} was similar to 2017 for all species, ranging from 63 percent for steelhead and Chinook to 86 percent for coho (Table 3.4-1).

Based on the results of the 2019 study, once fish entered the forebay they appeared to find and enter the FSC at a high rate. The encounter rate (P_{ENC}) ranged from 85 percent for juvenile Chinook to 95 percent for coho. Entrance efficiency (P_{ENT}) ranged from 78 percent for Chinook to 98 percent for coho. Analysis of 2D fish tracks revealed that fish locate the FSC entrance shortly after entering the ZOI, and the highest density of fish positions in the ZOI was found to be immediately in front of and inside the NTS entrance. Although P_{ENC} was similar to 2017 results, 2019 P_{ENT} significantly increased when compared to the 2017 study when fish were similarly positioned in the vicinity of the collector but failed to enter in large numbers. These results suggest that improvements made to the FSC since the 2017 study are effective at encouraging fish to enter the NTS. However, retention efficiency (P_{RET}) of the FSC was variable, ranging from 28 percent for steelhead and 65 percent for Chinook and coho. Though 2019 P_{RET} represents further gains for Chinook and coho, steelhead P_{RET} was lower than in 2017. When taken in light of increased steelhead collection probability in 2018, these results suggest that attraction flow modifications or other operational changes made after the 2018 study may have had varying effects. Of the 279 fish of all three species that were tracked in the ZOI, 93 percent were detected inside the entrance of the NTS (P_{ENT}), but only 60 percent of the fish that entered the NTS were collected (P_{RET}). Fish that migrate through the reservoir are entering the collector, but many are rejecting the collector once inside, suggesting the reach between the NTS and collection is the current bottleneck to achieving performance goals.

Acoustic telemetry data collected during the 2019 study enabled the analysis of fine scale movements in the collector, namely identifying when fish entered and exited the collection channel, which is the passage fish must travel through between the NTS and the FSC. Multivariate analysis using these data revealed that larger fish were most likely to reject the collector after traveling as far as the collection channel. Given the fact that all species experienced the same collection environment, but larger fish were significantly more likely to reject collection suggests that flow velocities within the collection channel have an asymmetric impact on fish of different sizes that may be independent of species. This “size effect” may be explained by larger fish being able to achieve burst velocities great enough to escape entrainment flows within the collector, and thus being able to make multiple visits and avoid collection. This may explain why steelhead P_{RET} declined at the same time that spring Chinook and coho P_{RET} increased: test steelhead were generally larger than other test fish and while increased attraction velocity encouraged fish of all sizes to enter the collector, larger fish were able to escape when faced with a condition that elicited an avoidance response. Finer scale observations are required to determine the location where fish are turning around.

Although diel period was not related to rejection within the collection channel, juvenile Chinook were collected predominantly at night (87 percent). Collection timing was more varied for coho and steelhead with about an even number of fish collected during the day and night.

Given the results of the study, it is thought that P_{RET} is now the major bottleneck of collection efficiency at the Swift FSC. PacifiCorp plans to retest collection efficiency through an acoustic tag study in the spring of 2020.

Table 3.4-1. Summary of seasonal corrected passage metrics for tagged fish released at the head of Swift Reservior by species.

Metric	Coho Salmon	Chinook	Steelhead	Total
Total tagged (n)[1]	300	155	70	525
Detected in the Forebay	175	88	40	303
P_{RES}[2]	86%	63%	63%	78%
Detected at ZOI	167	75	37	279
P_{ENC}[2]	95%	85%	93%	92%
Entered NTS	161	57	36	254
P_{ENT}[2]	98%	78%	97%	93%
Retained in NTS	46	7	21	74
P_{RET}[2]	65%	65%	28%	60%
Captured at FSC	156	42	11	209
Collection Efficiency (P_{CE})[2]	64%	51%	27%	55%

Note:

[1]It is estimated 26% of tags released were not activated.

[2]P_{RES}, P_{ENC}, P_{ENT}, P_{RET}, and P_{CE} were corrected to account for array detection efficiencies.

3.5 Swift FSC Injury and Survival

3.5.1 Overview/Methods

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 SA.

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 current M&E Plan (2017) assume that rates of fish injury and mortality found in subsampled fish would be representative of the general population. PacifiCorp is required to achieve at least 99.5 percent survival and less than (or equal) to 2.0 percent injury for smolts (Table 3.5-1). Parr life-stage was included with smolts for each species to calculated survival and injury. These metrics were calculated separately for fry.

Each day the FSC was operated, 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 $\leq$ 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 (2017), injury and survival rates were calculated daily and are shown in Equation 3.5-1 and Equation 3.5-2, respectively.

$$R_{Inj} = \frac{SS_{Inj}}{SS_{Total}}$$ **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.

$$\boldsymbol{CS} = S_{COL} * S_{TRAN}$$ **Equation 3.5-2**

Where:

CS = Observed combined collection and transport survival rate per species, and is the percentage of juvenile anadromous fish of each of the species collected that leave the Release Ponds alive.
SCOL = Survival probability through the collector; expressed as the ratio between the number of alive fish in the subsample and the total number of fish examined in the subsample; and
STRAN = Survival probability through the smolt transport system; expressed as the ratio of alive marked fish in the transport system to the total number of marked fish released in the transport system.

Note: CS was calculated for smolt (combined with parr), whereas only SCOL was recorded for fry. Fry were transported downstream in 2019, however once collection efficiency at the FSC reaches >60 percent, it is intended that this life-stage be returned to the reservoir.

3.5.2 Results/Discussion

Injury Rate

Combined annual injury rates for each target species ranged from 0 to 1.6 percent (Table 3.5-3). Steelhead kelts had the highest overall injury rate (1.6 percent), followed by coho fry (0.84 percent), juvenile coho (0.38 percent), cutthroat (0.32 percent), juvenile Chinook (0.19 percent), and steelhead (0.01 percent). As in previous years, descaling accounted for the greatest proportion of the injuries observed (84.8 percent) in all species, followed by open wounds (9.4 percent), bruising (5.8 percent), and fin damage (0.8 percent) (Figure 3.5-1). No injuries were observed among Chinook fry (n=31), steelhead fry (n=14), or cutthroat fry (n=4). Similarly, injuries were not observed on any of the adult steelhead (e.g., non-kelt) 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 percent.

PacifiCorp will continue to address the causes of injury in the future. Debris accumulation in both the smolt flume and adult tank have been a source of injury and mortality. In an effort to further reduce injury and mortality caused by debris loading, PacifiCorp is currently in the process of making modifications to both of these areas. A new starboard smolt flume is scheduled to begin fabrication in February 2020. This new flume will be identical to the port smolt flume that was commissioned in 2019, which was shown to decrease debris-related mortality and injury. The adult tank is also scheduled to be modified to include a traveling screen and automated debris conveyance system to remove debris from the holding tanks. PacifiCorp will continue to monitor the efficacy of these modifications into the future.

Table 3.5-3. Annual injury rates for target species collected at the FSC are shown with the associated 95 percent confidence interval.

	No. Injured [a]	No. Sampled [b]	Injury Rate (%)
Coho (Fry)	23	2,734	0.84 ± 0.34
Chinook (Fry)	0	64	0
Steelhead (Fry)	0	8	0
Cutthroat (Fry)	0	1	0
Combined (Fry)	**23**	**2,807**	**0.81 ± 0.33**
Coho (Parr & Smolt)	110	29,155	0.38 ± 0.02
Chinook (Parr & Smolt)	10	5,039	0.19 ± 0.06
Steelhead (Parr & Smolt)	1	1,029	0.1± 0.07
Cutthroat (Parr & Smolt)	1	307	0.32 ± 0.2
Combined (Parr & Smolt)	**122**	**35,530**	**0.34 ± 0.02**
Steelhead Adults	0	23	0
Steelhead Kelts	1	64	1.6 ± 3.04
Bull Trout	0	5	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.

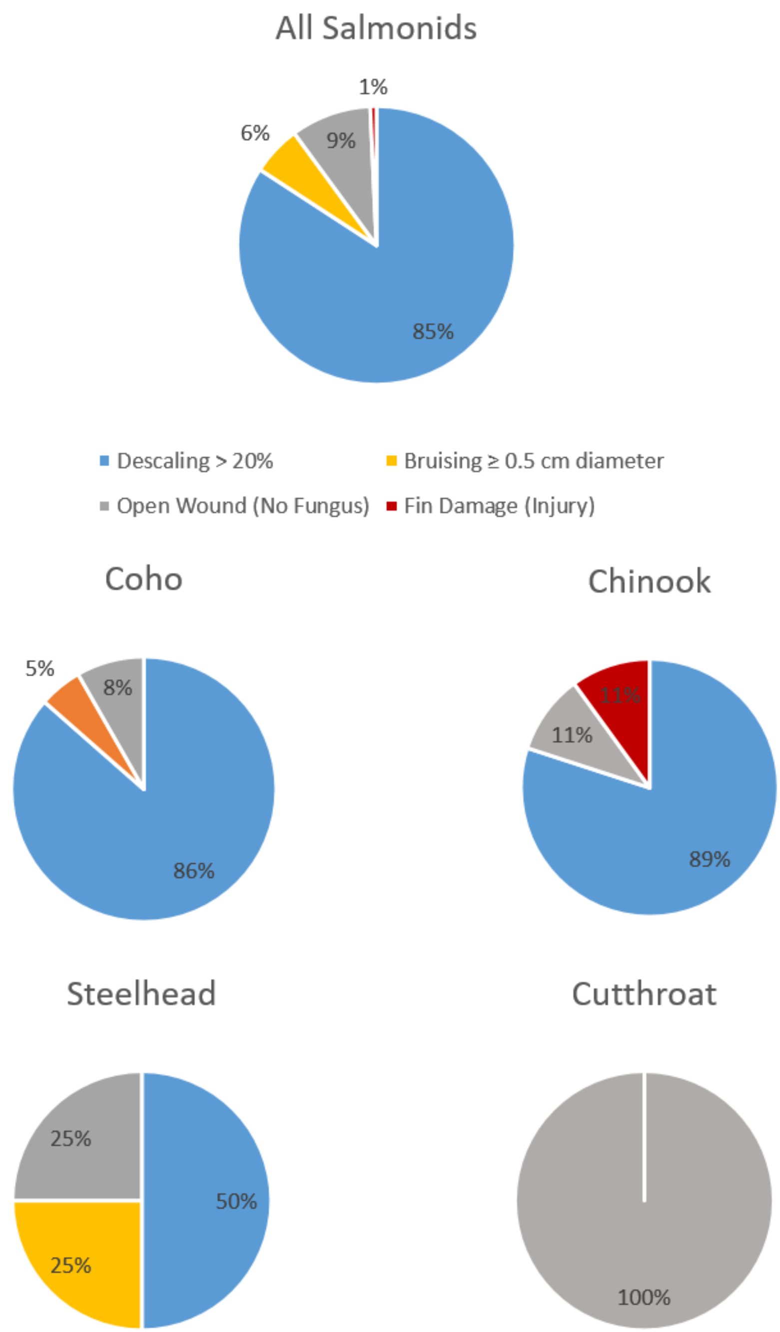

Figure 3.5-1. Composition of injury type occurrences by species in 2019. Percentages reflect the proportion of injury type observed of the total number of fish injured, not the total number of fish evaluated. Percentages reflect parr and smolts numbers sampled that are referenced in Table 3.5-3.

Survival Rate

Annual survival rates among all target species and life-stages passing through the FSC (S_{COL}) ranged from 78.2 to 100 percent (Table 3.5-4). Bull trout, steelhead fry and cutthroat fry had the highest overall survival rate (100 percent) followed by juvenile coho (99.8 percent), steelhead (99.7 percent), Chinook (99.2 percent), cutthroat (98.0 percent), and adult steelhead, including both fallback pre-spawning adults as well as kelts (78.2 percent)

Overall, the combined collection and transport survival rates (CS) for juvenile salmonids did not meet the CS performance standard for smolt and parr (≥99.5 percent) (Tables 3.5-5, 3.5-6). The primary driver behind the smolt survival standard not being met was due to a single fish kill event that took place during transport on June 1, 2019. In general, fry survival rates met the performance standard (≥98.0 percent) (Table 3.5-6), though coho fry survival (S_{COL}) was just slightly lower than the standard at 97.9 percent. Nearly all mortality observed onboard the FSC was associated with debris 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-yearly out-migrants (parr) and fry are prevalent. Modifications intended to reduce debris-induced mortality have been ongoing, and have included to date: 1) expansion of the fry holding to include a traveling screen to continually remove debris; and, 2) replacing the original fish conveyance pipe between the separator bars to the holding tanks with a larger, more open flume system to reduce debris accumulation and blockage. Ongoing modifications include replacing the existing fish separator bars with bars reconfigured as to prevent debris impingement and accumulation, as well as including a second traveling screen and debris removal system into the adult fish holding tank.

Table 3.5-4. Annual survival rates for juvenile salmonids (parr and smolt), cutthroat, bull trout, and adult steelhead collected at the Swift FSC (S_{COL}).

Species	No. of Mortalities	No. Sampled	S_{COL} Survival% (CS)	Combined Survival% with 95%CI
Coho Parr	6	3,030	99.8	99.3 ± 0.03
Coho Smolts	187	26,125	99.2	
Chinook Parr	4	1,526	99.7	99.1 ± 0.17
Chinook Smolts	42	3,513	98.8	
Steelhead Parr	0	63	100.0	99.8 ± 0.19
Steelhead Smolts	2	966	99.7	
Cutthroat(< 13 inches)	7	276	97.4	97.7 ± 0.9
Cutthroat (> 13 inches)	0	31	100.0	
Total	**288**	**35,530**	**Overall**	**99.1± 0.03**
Steelhead Adults	2	23	91.3	78.2 ± 8.68
Steelhead Kelts	17	64	73.4	
Bull Trout	0	5	100	100

Table 3.5-5. Combined annual survival rates for juvenile salmonids (parr and smolt) collected and transported from the Swift FSC (CS).

Species	No. of S_{TRAN} Mortalities (Tagged Fish)	S_{TRAN} Survival%	Combined S_{COL} Survival% (from Table 3.5-4)	Combined Survival % (CS)
Coho	44	94.7	99.3	94.0
Chinook	7	98.6	99.1	97.7
Steelhead	0	100.0	99.8	99.8
Cutthroat	0	100.0	97.7	97.7

Table 3.5-6. Annual survival rates (S_{COL}) for salmonid fry.

Species	No. of Mortalities[5]	No. Sampled	Survival% (CS)
Coho Fry	55	2,734	97.9 ± 0.5
Chinook Fry	1	64	98.4 ± 3.0
Steelhead Fry	0	8	100.0
Cutthroat Fry	0	1	100.0
Bull Trout Fry	0	0	0.00
		Overall:	**98.0 ± 0.52**

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 SA 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/Methods

The SA requires that the Utilities achieve an overall downstream survival (ODS) rate of greater than (or equal) to 80 percent[6]. ODS is defined in Section 4.1.4 of the SA as:

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

[5] Fry were transported downstream in 2019, however once collection efficiency at the FSC reaches >60 percent, it is intended that this life-stage be returned to the reservoir. No mortality was observed during transport of fry downstream in 2019.

[6] An ODS of greater than or equal to 80 percent 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 percent. The parties to the SA acknowledge that ODS rates of 80 percent or 75 percent are aggressive standards and will take some time to achieve.

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 SA 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 Woodland Release Ponds located downstream of Merwin Dam (Figure 2.1-1). Estimates of ODS are to be developed initially for juvenile coho, Chinook, and steelhead. 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 SA, 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.

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 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 is shown in Equation 3.7-1.

$$\boldsymbol{ODS = S_{RES} * S_{COL} * S_{TRAN}} \qquad \textbf{Equation 3.7-1}$$

Where:

S_{RES} = Survival probability through reservoir; expressed as the ratio between the total number of marked fish release at the head of the reservoir and the total number of marked fish subsequently recaptured at the FSC;

S_{COL} = Survival probability through the collector; expressed as the ratio between the number of alive fish in the subsample and the total number of fish examined in the subsample;

S_{TRAN} = Survival probability through the smolt transport system; expressed as the ratio of alive marked fish in the transport system to the total number of marked fish released in the transport system.

3.7.2 Results/Discussion

Only PIT tag interrogations at the FSC and Woodland Release Ponds recorded on or before December 31, 2019 were included in the 2019 ODS study. Pooling data annually for 2019 S_{COL} was 0.993 for coho (n=31,889 total fish sampled), 0.991 for Chinook (n=5,103), 0.977 for cutthroat (n=307), and 0.998 for steelhead (n=1,029). While in operation the Woodland Release Ponds were inspected daily during 2019 for fish mortality. Only six dead PIT tagged Chinook pertaining to the ODS study were found in the Woodland Release Ponds. On June 1, 2019, an isolated fish kill occurred while smolts were being transported from the Swift FSC downstream to the Woodland Release Ponds. Forty-four PIT tagged juvenile coho and 1 tagged Chinook were recorded as part of the mortalities and added to the S_{TRAN} analysis. This results in a Chinook S_{TRAN} value of 0.986 and an S_{TRAN} for coho of 0.947. S_{TRAN} for steelhead and cutthroat was 1.0 or 100 percent.

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 March 5 to July 19, 2019. Low numbers of fish were captured by the screw trap in 2019. Because of inadequate numbers of fish to tag, no species received the required 996 tags from the screw trap alone. During the study period, only 1,064 coho, 223 Chinook, 51 cutthroat, and 280 steelhead were PIT tagged and released for the ODS study. Of the PIT tagged fish, 413 coho, 168 Chinook, and 78 steelhead were non-naïve fish that were captured and tagged at the FSC then transported and released at the head of the reservoir. The resulting annual S_{RES} estimates are 45 percent for coho, 25 percent for Chinook, 7.8 percent for cutthroat and 8.2 percent for steelhead. Combining each species respective S_{RES}, S_{COL}, and S_{TRAN} values gives an estimate for ODS (Table 3.7-1). The ODS 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 (performance standard for all species is ≥ 80 percent).

Species	Tagged and Released in 2019	FSC Recaptured in 2019	S_{RES}	S_{COL} (%)	S_{TRAN} (%)	2019 ODS (%) with ±95% CI
Coho	1,064	481	45.0	99.3	94.7	42.3 ± 3.0
Chinook	223	56	25.0	99.1	98.6	24.4 ± 5.7
Steelhead	280	23	8.2	99.8	100	8.2 ± 3.2
Cutthroat	51	4	7.8	97.7	100	7.6 ± 7.4

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 2018 ODS estimates are summarized below in Table 3.7-2. An additional 130 tagged coho, 7 steelhead, 1 Chinook, and 8 cutthroat from the 2018 ODS study were captured by the FSC during 2019. No additional tags from the 2017 ODS study were captured in 2019.

Table 3.7-2. 2018 adjusted annual ODS estimate for each species (functionally S_{RES} as the release ponds were not yet in operation) is shown (performance standard for all species is ≥ 80 percent).

Species	Tagged and Released in 2018	FSC Recaptured 2018	2018 ODS (%) with ±95%CI	FSC Recaptured 2019	Total Recaptured (Combined Years)	2018 Combined ODS (%) with ±95%CI
Coho	1,073	290	27 ± 2.7	130	420	39 ± 3.9
Chinook	408	97	23 ± 4.1	1	98	24 ± 4.1
Steelhead	439	191	44 ± 4.6	7	198	45 ± 4.7
Cutthroat	96	18	19 ± 7.8	8	26	27 ± 8.9

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 8,495 fish were captured at the Merwin Trap in 2019 (Table 4.1-1). Among the species collected, early coho accounted for the largest proportion of fish captured (n=2,612) followed by winter steelhead (n=1,896), summer steelhead (n=1,865), spring Chinook (n=998), late coho (n=762), fall Chinook (n=309), cutthroat (n=45), sockeye salmon (n=11), and resident rainbow trout (n=6). Of the fish captured, several were recaptured fish that had already passed through the trap once. Recaptured fish counts include 468 hatchery summer steelhead, 90 blank wire tag winter steelhead, and three wild sockeye salmon.

A total of 1,389 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 WDFW Recycle

Program. A total of 468 summer steelhead were then recaptured at Merwin Trap. Once recaptured, fish were then sent to surplus.

Approximately 39.0 percent of all early run coho that returned to Merwin trap in 2019 were of natural origin. This proportion is similar to years 2016 (34.5 percent) and 2017 (54.4 percent), and higher than years 2014 (11.2 percent) and 2015 (6.5 percent). A total of 54 coho, five winter steelhead, and five cutthroat trout previously PIT tagged, returned to the Merwin Trap in 2019. The majority of these fish had been tagged at the Swift FSC as juveniles in previous years. All PIT record details are currently being uploaded to the PTAGIS database.

A total of 3,086 early coho, 2,501 late-coho, 1,009 unclipped winter steelhead (combined blank wire tag program adult and true natural origin adult), 115 Chinook, and 45 cutthroat were transported upstream and released above Swift Dam as part of the reintroduction program in 2019 (Table 4.1-2). Of the 3,086 early-coho that were transported upstream, 1,985 were collected at the Merwin Trap and 1,101 were collected at Lewis River Hatchery. The majority of late-coho that were transported upstream in 2019 were collected at Lewis River Hatchery (n = 2,111). An additional 390 late-coho were collected at the Merwin Trap. Of the 115 spring Chinook that were transported upstream in 2019, 109 were collected at Merwin Trap, and six were collected at Lewis River Hatchery. Of the 1,009 wild winter steelhead transported upstream, 1,008 were collected at the Merwin Trap, and one was collected at Lewis River Hatchery. Twelve of the transported wild winter steelhead were of natural origin, and 997 were blank wire tag fish. Wild origin late-coho were transported upstream only after meeting brood incorporation goals. All cutthroat that were transported upstream were collected at the Merwin Trap.

Table 4.1-1. Total number of salmonids collected at Merwin Trap during 2019. 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]	337	213	100	116	74	125	12	12	9									**998**	11.7
Fall Chinook	68	43	33	25	5	4	70	51	10									**309**	3.6
Early Coho	567	589	142	119	133	44	389	430	199									**2,612**	30.5
Late Coho	173	189	31	26	28	2	152	128	33									**762**	8.9
Summer Steelhead	467	922					5	3							124	344		**1,865**	21.8
Winter Steelhead	317	422					51	25					513	478	50	40		**1,896**	22.7
Sockeye Salmon							2	6								3		**11**	0.1
Chum Salmon																			0
Pink Salmon																			0
Cutthroat (>13 inches)																	45	**45**	0.5
Cutthroat (< 13 inches)																			0.0
Rainbow (< 20 inches)																	6	**6**	0.1
Bull Trout (> 13 inches)																			0
Bull Trout (< 13 inches)																			0
																	Total	**8,495**	100

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

Table 4.1-2. Total salmonids transported above Swift Dam in 2019 (totals include Merwin Trap and Lewis River Hatchery Trap captures).

Species	Male	Female	Jack	Not sexed	Female:Male Ratio	Jack:Adult Ratio	Total
Spring Chinook	10	11	88	-	0.1	4.19	***109***
Early Coho	1,319	1,535	232	-	0.99	0.08	***3,086***
Late Coho	1,627	838	36	-	0.50	0.01	***2,501***
Winter Steelhead	527	482	-	-	0.91	-	***1,009***
Cutthroat >13"	-	-	-	45	-	-	***45***
Bull Trout >13"	-	-	-	-	-	-	***0***
						Total	***6,750***

4.2 Adult Passage Survival

4.2.1 Overview/Methods

Section 9.2.1(h) of the SA requires upstream passage survival (UPS) of adult salmonids and bull trout to be equal to or greater than 99.5 percent. The methods to calculate adult passage survival are outlined in Objective 9 of the current M&E Plan (2017). Adult bull trout and cutthroat trout are defined as fish with FL 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; and
AD_{REL} = Number of dead adults at release site.

4.2.2 Results/Discussion

A total of 6,750 adult salmonids (3,086 early coho, 2,501 late coho, 1,009 winter steelhead, 109 spring Chinook, and 45 cutthroat) were transported upstream throughout the migration period in 2019. Out of the 6,750 fish that were transported upstream, 1,617 were of natural origin (1,218 early coho, 351 late coho, 36 spring Chinook, and 12 winter steelhead). All cutthroat survived the trapping and transport processes resulting in a UPS of 100 percent. Late coho demonstrated the second highest overall survival rate (99.9 percent), followed by winter steelhead (99.8 percent), early coho (99.7 percent), and spring Chinook (94.5 percent). The majority (89.5 percent) of mortalities observed in 2019 occurred during the trapping process (nine early coho, five spring Chinook, two winter steelhead, and one late coho). The remaining 10.5 percent occurred during transport (1 early coho, and 1 spring Chinook). A total of 19 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 2019.

Species	Number Transported	Trap Mortalities	Transport Mortalities	Upstream Passage Survival (%)
Early Coho	3,086	9	1	99.7
Late Coho	2,501	1	0	99.9
Spring Chinook	109	5	1	94.5
Winter Steelhead	1,009	2	0	99.8
Coastal Cutthroat	45	0	0	100
Total	**6,750**	**17**	**2**	**99.7**

4.3 Adult Trap Efficiency

4.3.1 Overview/Methods

Adult trap efficiency (ATE) is defined in Section 4.1.4 of the SA 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 current M&E Plan (2107) defines a performance standard of 98 percent collection efficiency (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, respectively) 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 early findings was the installation of a single V-style fyke to prevent fish from returning to the tailrace once they have entered the trap. The V-style fyke was installed in November 2016. In addition, increased frequency of hopper operation was also 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 new V-style 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 Dam 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). In 2018 the trap-naïve group had a low sample size although statistically it was shown trap-naïve fish had a higher efficiency. 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.

The main goal of the 2019 Merwin Dam ATE study was to build on the 2018 study with the intention of achieving a larger sample of trap-naïve test fish. In 2019 an additional group of test fish was also created where trap non-naïve fish were tagged and released further downstream at the Pekins Ferry boat launch (trap non-naïve$_{PF}$). This additional group was introduced to asses if release location may effect performance between groups. This was because the historical release point for trap non-naïve fish had been at Merwin Dam boat launch, which is in close proximity (less than 0.2 mile) to the dam and trap entrance. Only winter steelhead were evaluated in the 2019 ATE study.

4.3.1 Results/Discussion

A detailed report of the fifth year of data collection (2019) for winter steelhead is provided in Appendix D.

Consistent with previous years, during the 2019 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 percent) than the rate at which they were captured (i.e., ATE_{test} of 84 percent; Table 4.3-1).

In general, adult steelhead continued to appear to be highly attracted to the tailrace and to the entrance of the Merwin Trap during the 2019 study. Evidence in support of this includes the following observations:

- The proportion of study fish reaching the tailrace was high (approximately 95 percent).
- Winter steelhead generally exhibited high transition rates moving upstream towards the tailrace and trap from downstream locations.
- Few (n = 4) steelhead were detected in neighboring tributaries suspected of attracting strays.
- Non-Naïve$_{PF}$ returned to the tailrace and trap at high rates, despite being released approximately 29 km downstream from Merwin Dam.
- Once steelhead entered the tailrace in 2019, the path most frequently used was along the south side of the tailrace where the trap entrance is located.
- 94 percent of fish that entered the tailrace located the trap entrance (i.e., P_{EE}).
- P_{EE} was high for all release groups (range = 87-100 percent).

Results from the 2019 study also indicated that, non-naïve fish when compared to naïve and non-naïve$_{PF}$ fish:

- Non-naïve fish exhibited more milling behavior in the tailrace than either naïve or non-naïve$_{PF}$ fish.

- Non-naïve fish visited twice as many RT receiver sites on average, compared to either naïve or non-naïve$_{PF}$ fish. This was in spite of non-naïve$_{PF}$ fish being released approximately 28 km *further downstream* from Merwin Dam compared to non-naïve fish.
- Non-naïve fish spent 40 more hours in the tailrace on average, compared to either naïve or non-naïve$_{PF}$ fish.
- Non-naïve fish used the most stored somatic energy after release of any group.
    a. Non-naïve and non-naïve$_{PF}$ fish used significantly more (17.5 and 15 fold more, respectively) energy than naïve fish, based on measurements of muscle lipid content taken before release and after re-capture at Merwin Dam.
    b. Non-naïve and non-naïve$_{PF}$ fish used similar amounts of energy following release, again, despite non-naïve$_{PF}$ fish having to swim upstream an additional approximately 28 km to reach Merwin Dam.

Evidence from two years of study comparing naïve and non-naïve fish indicate non-naïve fish exhibit less directed movements toward the trap compared to naïve fish. Overall, naïve steelhead have outperformed non-naïve fish in both study years, and ATE_{test} for naïve fish in 2018 (100 percent) and 2019 (95 percent) was the highest across all study years thus far. Despite high ATE for naïve fish, there was still a low statistical probability (18 percent) that naïve fish met or exceeded the 98 percent performance standard for passage efficiency at Merwin Dam, reflecting uncertainty deriving from the modest sample size for this group.

Table 4.3-1. Summary of passage metrics for tagged fish released into the tailrace of Merwin Dam in 2019.

Metric	Coho Salmon	Spring Chinook	Steelhead
Total Tagged (n)	NA	NA	107
Trap Non-Naïve	NA	NA	41
Trap Naïve	*NA*	*NA*	*23*
Trap Non-Naïve$_{PF}$	*NA*	*NA*	*43*
Entered the Tailrace	NA	NA	102
Trap Non-Naïve	*NA*	*NA*	39
Trap Naïve	*NA*	*NA*	22
Trap Non-Naïve$_{PF}$	NA	NA	41
Entered the Trap	NA	NA	96
Trap Non-Naïve	*NA*	*NA*	34
Trap Naïve	*NA*	*NA*	22
Trap Non-Naïve$_{PF}$	*NA*	*NA*	40
Trap Entrance Efficiency (P_{EE})	NA	NA	94% (88-97%)
Trap Non-Naïve	*NA*	*NA*	*87% (88-97%)*
Trap Naïve	*NA*	*NA*	*100% (91-100%)*
Trap Non-Naïve$_{PF}$	*NA*	*NA*	*98% (81-97%)*
Captured	NA	NA	86
Trap Non-Naïve	NA	NA	33
Trap Naïve	NA	NA	21
Trap Non-Naïve$_{PF}$	NA	NA	32

Metric	Coho Salmon	Spring Chinook	Steelhead
Collection Efficacy (P_{CE})	NA	NA	84% (76-90%)
Trap Non-Naïve	*NA*	*NA*	*85% (81-93%)*
Trap Naïve	*NA*	*NA*	*95% (87-99%)*
Trap Non-Naïve$_{PF}$	*NA*	*NA*	*78% (63-88%)*

4.4 Spawn Timing, Distribution, and Abundance of Transported Fishes

4.4.1 Overview/Methods

Section 9.2.2 of the SA identified the need to determine the spawn timing, distribution, and abundance for transported anadromous species that are passed upstream of Merwin Dam, which is included in the M&E Plan as Objective 15. 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 2019. 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 current M&E Plan.

4.4.2 Results/Discussion

Coho and Chinook Salmon

Data collection on the spawn timing, distribution, and abundance of transported spring Chinook and coho was completed the end of December 2019. The reports summarizing these data are provided in Appendix E. In summary, a total of 182 coho redds were counted and a total of six redds were attributed to spring Chinook spawning. Redd counts and estimates of spawning success suggest that most (if not all) adult Chinook females transported upstream during 2019 spawned (similar to previous years when Chinook were transported upstream to spawn). Similar to previous years, Chinook appear to have distributed throughout the Muddy River watershed (Clearwater Creek and Muddy River mainstem) and North Fork Lewis River mainstem based on 2019 live Chinook and carcass observations in early-October. 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, 2018, and 2019 when weekly surveys were conducted over the entire mainstem during the Chinook spawning season for the purpose of Bull Trout spawning surveys.

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 0.54 (bootstrap 95 percent confidence interval of 0.26 to 0.92) as the proportion of transported female coho that spawned in 2019, which is within the range of estimates made over the previous 5-year period. Though coho redds were well distributed through the entire stream network upstream of Swift Dam, unusually low flows in the reservoir tributaries in combination with low reservoir conditions through the majority of the coho spawning season likely limited spawning habitat for early and late-coho, which have been shown to widely use the reservoir tributaries for spawning in previous years. Furthermore, spawning success may have been reduced by coho selecting to spawn in the drawdown zone due to low stream flow and low reservoir conditions. Though not specifically quantified, some coho were observed spawning in the drawdown zones of reservoir tributaries and the mainstem North Fork Lewis River. The sample frame only covers the stream network of available habitat upstream of the reservoir full pool elevation. Therefore, if coho spawn below the full pool elevation within the drawdown zone, these redds are not counted, and therefore are treated as unsuccessful spawning events.

It is important to note that over 30 percent of coho were transported upstream in late-December after seasonally closed roads and snow limited access to a large portion of the Muddy River watershed. This spawning survey was originally 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 somewhat problematic due to inherent survey limitations such as seasonally closed roads, typical snow accumulation, and typical large storms that decrease stream visibility in the late-fall and early-winter.

Winter Steelhead

Data entry, QA/QC, summary and analysis is still ongoing for aerial 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 2019 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/Methods

An analysis of ocean recruitment is stipulated in the SA 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 SA 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 current the M&E Plan **(**2017**)**. It will take at least five years of analysis before investigators can confidently report ocean recruit numbers and begin evaluating hatchery goals for the Lewis River. Given dramatic improvements in collection efficiency of out-migrants at the FSC in 2019, it is anticipated that this analysis will begin in 2024.

6.0 PERFORMANCE MEASURES FOR INDEX STOCKS

6.1 Overview/Methods

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/Methods

As called for in Section 9.7 of the SA, 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 (USGS) and University of Washington (UW), 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

ACCLIMATION POND DECOMMISSIONING REPORT – FERC FILING (DECEMBER13, 2019)

PACIFICORP

Pacific Power |
Rocky Mountain Power
825 NE Multnomah, Suite 1800
Portland, Oregon 97232

Electronically filed December 13, 2019

Ms. Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street, NE
Washington, DC 20426

Subject: Swift No. 1 Hydroelectric Project, FERC No. P-2111 Order Amending Lewis River Hatchery and Supplementation Plan Pursuant to Article 401 and Approving Lewis River Acclimation Pond Plan, January 4, 2018 - Report on Acclimation Pond Decommissioning

Dear Ms. Bose:

On December 5, 2017, PacifiCorp filed with the Federal Energy Regulatory Commission a request for Commission approval to decommission the Muddy River, Clear Creek and Crab Creek juvenile fish acclimation pond facilities located upstream of the Swift No. 1 Hydroelectric Project (P-2111). On January 4, 2018 the Commission responded with an order approving the December 5, 2017 request. As conditions of this approval, the Director ordered a final report be prepared which summarizes the decommissioning efforts, as well as, a plan and schedule for the proposed direct release program. This letter serves to satisfy these requests. As ordered, this letter report was provided to the Lewis River Aquatic Coordination Committee (ACC) for a 30-day review and comments received are included as **Appendix A**.

All three acclimation ponds have been successfully removed with decommissioning occurring in the summers of 2018 (Muddy River site) and 2019 (Clear Creek and Crab Creek sites). More specifically, Muddy River decommissioning began on August 20, 2018 and was completed including restoration actions on October 12, 2018. Clear and Crab Creeks were decommissioned at the same time with work beginning on August 19, 2019 and final site restorations occurring on November 1, 2019. A final walk through was conducted with the US Forest Service (USFS) on November 5, 2019. The USFS representative (Mr. Greg Robertson) expressed satisfaction with the completed projects. It is anticipated that the USFS Special Use Permit will be closed in the Spring of 2020 once it is confirmed that newly planted vegetation has achieved a 70% survival rate. Please see before and after photos of the completed projects and restoration included as **Appendix B** to this letter.

As part of initial decommissioning actions, fish salvages were conducted at each of the three locations. At the Muddy River site, a "push" cofferdam was constructed creating a berm separating the work from the active channel of the Muddy River. It was not anticipated that fish would be located within the isolated area and this presumption was confirmed by PacifiCorp fish biologists; no fish were found in this isolated area. At the Clear Creek site, a total of 16 juvenile coho and 18 banded sculpin were recovered from the work area and relocated to the active channel. At the Crab Creek site, no fish were recovered but one rough skinned newt was collected and relocated outside of the work area.

In response to the Commission's January 4, 2018 Order, PacifiCorp, through discussions with interested stakeholders, determined the future method to acclimate fish in the upper Lewis River watershed. On May 31, 2018, the Hatchery and Supplementation (H&S) subgroup of the Lewis River Aquatic Coordination Committee (ACC) met to discuss the Spring Chinook Acclimation Program upstream of Swift Dam. The original program called for annually placing 100,000 hatchery reared juvenile spring Chinook salmon into various acclimation sites upstream of Swift Reservoir. Fish would then be held for up to a month before being released into adjacent tributaries 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 native and hatchery spring Chinook adults transported upstream of the dam in 2017 and 2018 distributed and 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 at specific locations may not be necessary, and that releasing an additional 100,000 fish in the lower Lewis River to return as adults and be taken upstream would be a better strategy to meet program goals. PacifiCorp developed a release strategy memo (**Appendix C**) that outlined three potential options for annually releasing the 100,000 spring Chinook smolts formally allocated to the upper basin acclimation ponds over the next five (5) years (2019-2024). After review of the three options, the H&S subgroup recommended that beginning in 2019, all juvenile spring Chinook formally allocated to the upper basin release ponds be fully integrated into the existing lower Lewis River hatchery spring Chinook program; thereby increasing the overall annual hatchery program goal from 1.25 to 1.35 million juveniles per year. By increasing hatchery production in the lower river and ultimately gaining returning adults, more adults will be available to be transported upstream as part of the reintroduction efforts. This increase in fish numbers will also help to increase sample sizes for the spring Chinook as part of the ongoing H&S release strategy evaluation. This action was discussed and approved by the ACC at their June 14, 2018 Meeting, followed by an additional 7-day review period for absentee ACC representatives and approved without further comment on June 29, 2018 (**Appendix D**).

Monitoring of the spawn timing, distribution, and abundance of transported adult spring Chinook upstream of Swift Dam will continue as described in the current 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. If annual spawning surveys show that transported spring Chinook are not distributing throughout the available spawning habitat upstream of Swift Dam, contrary to the 2017 and 2018 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 and the adaptive management process.

This letter has been filed electronically. The security classification of each component in this packet is shown in the enclosure table. If you have any questions concerning this document, please contact Todd Olson at (503) 813-6657.

Sincerely,

Todd Olson
for

Mark A. Sturtevant
Vice President, Renewable Resources

MAS: BCH: km

Encl:	Letter – Public
	Appendix A: Email to ACC for 30-day review & comment period, November 7, 2019 – Public
	Appendix B: Acclimation Pond before and after photos – Public
	Appendix C: Release Strategy Memo to the H &S Subgroup, June 29, 2018 – Public
	Appendix D: June 29, 2018 ACC Final Approval of Release Strategy Memo

eFile:	Kimberly D. Bose, Secretary Via eLibrary at www.ferc.gov

Appendix A

McCune, Kimberly

From: McCune, Kimberly
Sent: Thursday, November 7, 2019 9:24 AM
To: Amanda Froberg; Amelia Johnson; Asher, Eli; Bill Sharp; Brice Crayne; Bryce Glaser; Carol Serdar; David Howe; Denise Smee; Doyle, Jeremiah; Ed Meyer; Ferraiolo, Mark; Hudson, Michael; James Byrne; James H Malinowski; Jonathan Stumpf; Joshua Ashline; 'Kale Bentley'; Karchesky, Chris; Katie Pruit; Kelley Jorgensen; Lesko, Erik; Mariah Stoll-Smith Reese; Michelle Day; Morgan, David; Nathan Reynolds; Olson, Todd; Peggy Miller; Pienovi, Levi; Rhidian Morgan; Roberts, Aaron; Robertson, Greg -FS; 'Ruth Tracy'; Sam Gibbons; Samuel Kolb; Steve Manlow; Steve West; Taylor Aalvik; Tim Romanski; Tom Sinclair; Weatherly, Briana; Wendy McDermott; Whitesel, Timothy
Subject: RESPONSE REQUESTED: Article 401 Lewis River Acclimation Pond Decommissioning Rpt, 30-day Review
Attachments: 11072019_LR_FERCDecommReport_AcclimationPonds_ACC Review Draft.pdf

Importance: High

Follow Up Flag: Follow up
Flag Status: Flagged

Attn: ACC Representatives

Please find attached a draft Acclimation Pond Decommissioning Report for a 30-day review and comment period.

We ask that you provide your comments **on or before close of business, Monday, December 9, 2019.**

Thank you.

Kimberly McCune
Sr. Business Administrator
PacifiCorp – Hydro Resources
825 NE Multnomah St., Suite 1800
Portland, OR 97232
Ph: (503) 813-6078

Responses to Comments Received on Lewis River Acclimation Pond Decommissioning Report, November 2019

Comment Number	Commentor	Date	Comment	PacifiCorp Response
1	WDFW	11/7/2019	Requested a variety of houskeeping changes and sentence structure	All requested changes incorporated into the final document
2	WDFW	11/7/2019	Add Release strategy memo as an Appendix	Accepted and included as Appendix C
3	WDFW	11/7/2019	Add ACC June 2018 approval of release strategy memo	Accepted and included as Appendix D

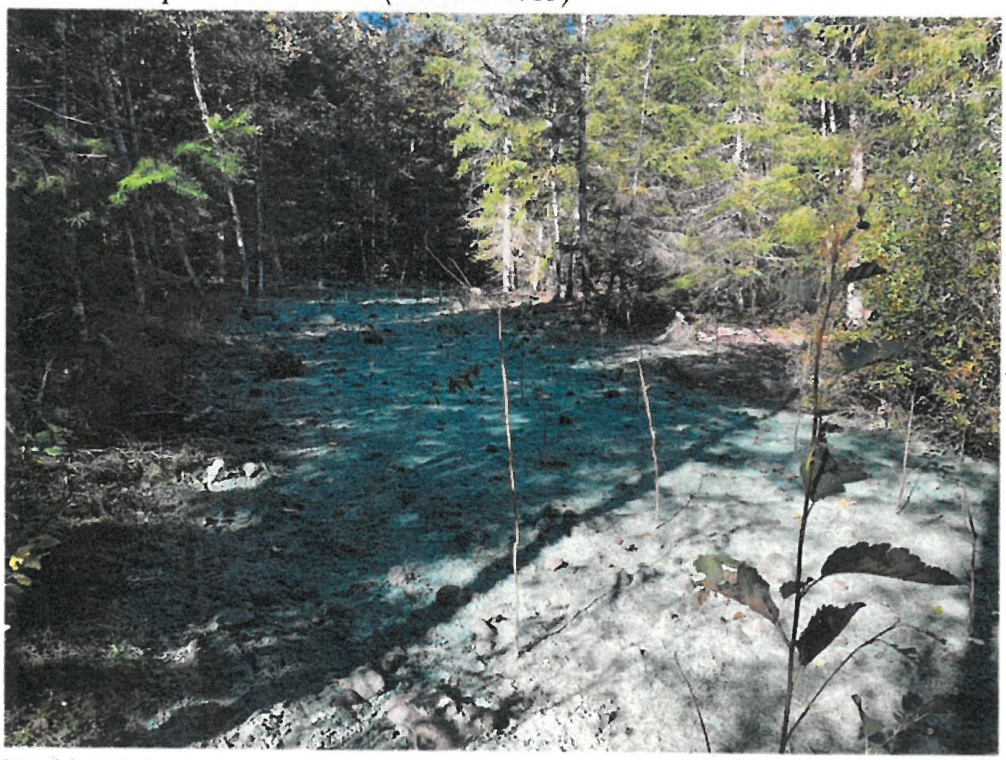
Appendix B

Appendix B

1. Muddy River Acclimation Pond post construction (October 2013)

2. Crab Creek post construction (July 2016)

3. Clear Creek post construction (October 2013)



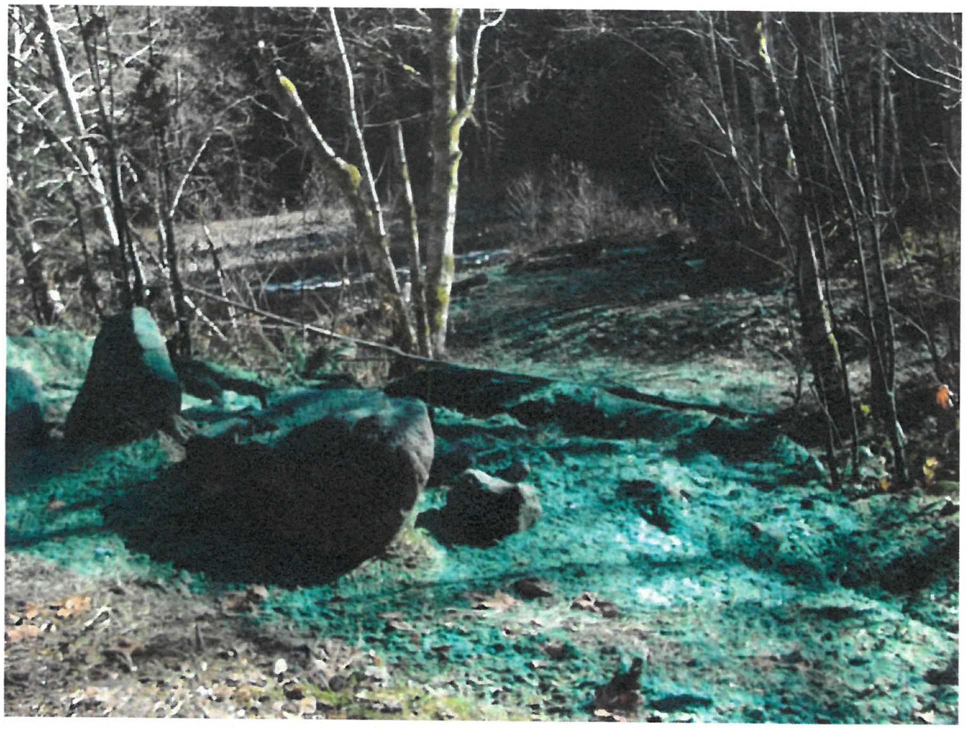
4. Muddy River post decommissioning (August 2018)

5. Clear Creek post-decommissioning (September 2019)

6. Crab Creek post-decommissioning (September 2019). Note final erosion control (jute matting) was installed the day after this photo was taken.

7. Crab Creek post-decommissioning. Note the erosion control, jute matting and native plantings (November 5, 2019)

8. Crab Creek fully restored at intake location. Note the stream has been restored to the maximum extent practical to match pre-construction conditions (November 5, 2019)



9. Clear Creek intake location restored, hydroseeded and planted with native plantings (November 5, 2019).

10. Clear Creek post-decommissioning. Note the constructed berm has been breached to re-connect Clear Creek to the floodplain (November 5, 2019).

Appendix C

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.

References

Jones, R.N., and R. Bottomley 1997. An evaluation of adipose fin clip versus left ventral fin clip as mass marks for hatchery spring Chinook salmon at Kooskia National Fish Hatchery, Idaho, dated May 1997. https://www.fws.gov/lsnakecomplan/Reports/FWS_Field_Stations/Idaho%20FRO-Project%20Reports/FINCLIP.Kooskia.pdf

Olson, D.E., and B.C. Cates. Undated. Differential performance of ventral fin clipped and adipose fin clipped/coded-wire tagged spring Chinook salmon at Warm Springs National Fish Hatchery, Oregon (1987-1989 brood year).
https://www.fws.gov/columbiariver/publications/VENTRALFINCLIP.pdf

Appendix D

McCune, Kimberly

From: McCune, Kimberly
Sent: Friday, August 10, 2018 9:10 AM
To: Amanda Froberg; Amelia Johnson; Asher, Eli; Bob Rose; Brice Crayne; Bryce Glaser; Bryce Michaelis; Daniel Rawding; David Howe; Denise Smee; Doyle, Jeremiah; Ed Meyer; Ferraiolo, Mark; Greg Robertson; Hudson, Michael; James Byrne; James H Malinowski; Jonathan Stumpf; Joshua Ashline; 'Kale Bentley'; Karchesky, Chris; Kelley Jorgensen; Lesko, Erik; Mariah Stoll-Smith Reese; Morgan, David; Nathan Reynolds; Olson, Todd; Peggy Miller; Pienovi, Levi; Rhidian Morgan; Roberts, Aaron; 'Ruth Tracy'; Sam Gibbons; Samuel Kolb; Serdar Carol; Steve Manlow; Steve West; Taylor Aalvik; Tim Romanski; Tom Wadsworth; Weatherly, Briana; Wendy McDermott; Whitesel, Timothy
Subject: RE: ACC Approved Subgroup Recommendations; Acclimation Program spring Chinook Release Strategies - FINAL
Attachments: 06292018_LR_AccPond_ReleaseStrategy.pdf

Attn: ACC Representatives

Please be advised that the attached document has been posted to the Lewis River website. A link has been provided below for your convenience.

http://www.pacificorp.com/content/dam/pacificorp/doc/Energy_Sources/Hydro/Hydro_Licensing/Lewis_River/li/acc/06292018_LR_AccPond_ReleaseStrategy.pdf
Thank you.

Kim

From: McCune, Kimberly
Sent: Friday, June 29, 2018 8:10 AM
To: Amanda Froberg <afroberg@cowlitzpud.org>; Amelia Johnson <ajohnson@lcfrb.gen.wa.us>; Asher, Eli <easher@cowlitz.org>; Bob Rose <rosb@yakamafish-nsn.gov>; Brice Crayne <bricecrayne@outlook.com>; Bryce Glaser <glasebgg@dfw.wa.gov>; Bryce Michaelis <bmichaelis@fs.fed.us>; Daniel Rawding <Daniel.Rawding@dfw.wa.gov>; David Howe <David.Howe@dfw.wa.gov>; Denise Smee <dsmee@lcfrb.gen.wa.us>; Doyle, Jeremiah <Jeremiah.Doyle@pacificorp.com>; Ed Meyer <ed.meyer@noaa.gov>; Ferraiolo, Mark <Mark.Ferraiolo@pacificorp.com>; Greg Robertson <gregrobertson@fs.fed.us>; Hudson, Michael <michael_hudson@fws.gov>; James Byrne <byrnejim7@gmail.com>; James H Malinowski <jim.malinowski@icloud.com>; Joshua Ashline <Joshua.ashline@noaa.gov>; 'Kale Bentley' <kale.bentley@dfw.wa.gov>; Karchesky, Chris <Chris.Karchesky@pacificorp.com>; Kelley Jorgensen <kjorgensen@pnfarm.com>; Lesko, Erik <Erik.Lesko@pacificorp.com>; Mariah Stoll-Smith Reese <mariah@lelooska.org>; Morgan, David <dmorgan@pnfarm.com>; Nathan Reynolds <nreynolds@cowlitz.org>; Olson, Todd <Todd.Olson@pacificorp.com>; Peggy Miller <peggy.miller@dfw.wa.gov>; Pienovi, Levi <Levi.Pienovi@pacificorp.com>; Rhidian Morgan <rmmorgan@pnfarm.com>; Roberts, Aaron <Aaron.roberts@dfw.wa.gov>; 'Ruth Tracy' <rtracy@fs.fed.us>; Samuel Kolb <samuel.kolb@dfw.wa.gov>; Serdar Carol <cser461@ECY.WA.GOV>; Steve Manlow <smanlow@lcfrb.gen.wa.us>; Steve West <swest@lcfrb.gen.wa.us>; Taylor Aalvik <taylor.a@cowlitz.org>; Tim Romanski <tim_romanski@fws.gov>; Tom Wadsworth <Thomas.Wadsworth@dfw.wa.gov>; Weatherly, Briana <Briana.Weatherly@pacificorp.com>; Wendy McDermott <wmcdermott@americanrivers.org>; Whitesel, Timothy <Timothy_Whitesel@fws.gov>
Subject: ACC Approved Subgroup Recommendations; Acclimation Program spring Chinook Release Strategies

Attn: ACC Representatives

Please be advised that PacifiCorp did not receive objection to the recommended Acclimation Program spring Chinook release strategies. The attached memorandum will be finalized and posted to the Lewis River website.

Thank you, everyone.

Kimberly McCune
Sr. Business Administrator
PacifiCorp – Hydro Resources
825 NE Multnomah St., Suite 1800
Portland, OR 97232
Ph: (503) 813-6078

From: McCune, Kimberly
Sent: Monday, June 18, 2018 4:16 PM
To: Amanda Froberg <afroberg@cowlitzpud.org>; Amelia Johnson <ajohnson@lcfrb.gen.wa.us>; Asher, Eli <easher@cowlitz.org>; Bob Rose <rosb@yakamafish-nsn.gov>; Brice Crayne <bricecrayne@outlook.com>; Bryce Glaser <glasebgg@dfw.wa.gov>; Bryce Michaelis <bmichaelis@fs.fed.us>; Daniel Rawding <Daniel.Rawding@dfw.wa.gov>; David Howe <David.Howe@dfw.wa.gov>; Denise Smee <dsmee@lcfrb.gen.wa.us>; Doyle, Jeremiah <Jeremiah.Doyle@pacificorp.com>; Ed Meyer <ed.meyer@noaa.gov>; Ferraiolo, Mark <Mark.Ferraiolo@pacificorp.com>; Greg Robertson <gregrobertson@fs.fed.us>; Hudson, Michael <michael_hudson@fws.gov>; James Byrne <byrnejim7@gmail.com>; James H Malinowski <jim.malinowski@icloud.com>; 'Kale Bentley' <kale.bentley@dfw.wa.gov>; Karchesky, Chris <Chris.Karchesky@pacificorp.com>; Kelley Jorgensen <kjorgensen@pnfarm.com>; Lesko, Erik <Erik.Lesko@pacificorp.com>; Mariah Stoll-Smith Reese <mariah@lelooska.org>; 'Michelle Day' <michelle.day@noaa.gov>; Morgan, David <dmorgan@pnfarm.com>; Nathan Reynolds <nreynolds@cowlitz.org>; Olson, Todd <Todd.Olson@pacificorp.com>; Peggy Miller <peggy.miller@dfw.wa.gov>; Pienovi, Levi <Levi.Pienovi@pacificorp.com>; Rhidian Morgan <rmmorgan@pnfarm.com>; Roberts, Aaron <Aaron.roberts@dfw.wa.gov>; 'Ruth Tracy' <rtracy@fs.fed.us>; Samuel Kolb <samuel.kolb@dfw.wa.gov>; Serdar Carol <cser461@ECY.WA.GOV>; Steve Manlow <smanlow@lcfrb.gen.wa.us>; Steve West <swest@lcfrb.gen.wa.us>; Taylor Aalvik <taylor.a@cowlitz.org>; Tim Romanski <tim_romanski@fws.gov>; Tom Wadsworth <Thomas.Wadsworth@dfw.wa.gov>; Weatherly, Briana <Briana.Weatherly@pacificorp.com>; Wendy McDermott <wmcdermott@americanrivers.org>; Whitesel, Timothy <Timothy_Whitesel@fws.gov>
Subject: RESPONSE REQUESTED: ACC Approved Subgroup Recommendations; Acclimation Program spring Chinook Release Strategies
Importance: High

Attn: ACC Representatives

Please be advised that at the June 14, 2018 meeting, the ACC approved recommendations by the Hatchery and Supplementation Subgroup with respect to release strategies of Acclimation Program spring Chinook. Of the three (3) strategies proposed in a PacifiCorp memo provided to the Subgroup (see attached), the ACC agreed that Option 3 should be implemented for fish currently being held at Speelyai Hatchery, and that Option 1 should be implemented beginning with Brood Year 2018 (released in year 2019) subject to annual review by the H&S Subgroup.

A summary of each recommended strategy is provided below:

For the 2018 release group only (Option 3): Acclimation program spring Chinook currently being held at Speelyai Hatchery will be released in November 2018 at the Woodland Release Ponds. Because of their current size, they cannot be integrated into the ongoing release strategy evaluation. All smolts will retain their adipose fins but will be differentially marked with a ventral fin clip (side to be determined) to identify this group from true NOR's upon their return as adults.

For release groups after 2018 (Option 1): Beginning with the 2018 Brood Year, acclimation program fish will be fully integrated into the hatchery spring Chinook program. There will be no differential mark associated with these fish and spawning crosses involving NOR spring Chinook will end. This strategy will increase hatchery production of spring Chinook released into the North Fork Lewis River from 1.25 to 1.35 million per year.

The H&S Subgroup will continue to monitor the program on an annual basis and make recommendations to the ACC when appropriate or modifications are warranted.

Due to the absenteeism of several ACC Representatives at the meeting last week the ACC agreed that an additional 7-day review period is appropriate. Please respond to my attention by close of business Tuesday, June 26, 2018.

Thank you.

Kimberly McCune
Sr. Business Administrator
PacifiCorp – Hydro Resources
825 NE Multnomah St., Suite 1800
Portland, OR 97232
Ph: (503) 813-6078

APPENDIX B

UPPER LEWIS RIVER NUTRIENT ENHANCEMENT – 2019 FINAL REPORT

Lewis River Aquatic Coordination Committee Meeting

Date: Thursday, December 12, 2019

Time: 9:00 am – 12:00 pm

Location: Merwin Hydro Control Center
105 Merwin Village Court
Ariel, WA 98603

Meeting Topic: Upper Lewis River Nutrient Enhancement – Final Report

At the September 12, 2019 Lewis River Aquatic Coordination Committee (ACC) meeting, members agreed to the Project Proposal requesting the use of surplus hatchery adult coho carcasses for nutrient enhancement upstream of Swift Dam in fall 2019.

The carcasses were prepared and distributed through the support of the Lower Columbia Fish Enhancement Group (LCFEG) volunteers and Washington Department of Fish and Wildlife Hatchery Staff. Three locations were selected to receive carcasses. These locations were: 1) Clear Creek Bridge Site; 2) Lower Lewis River Falls - Crab Creek Bridge Site; and 3) Muddy River Bridge Site. All fish were marked by having their tails removed prior to seeding so that deposited carcasses would not impact spawning surveys.

Nutrient Enhancement efforts occurred on four (4) separate days in October 2019 (Table 1). A total of 1,850 adult coho carcasses were evenly distributed between all three locations. Nutrient Enhancement efforts were not completed in November due to lower than expected returning adult coho numbers and inclement weather conditions. Additional details regarding the 2019 effort are provided in Table 1.

Figure 1. Volunteers with the LCFEB distributing carcasses off the Muddy River Bridge (photo left) and near Lower Falls, North Fork, Lewis River (photo right).

Nutrient Enhancement - Final Report 2019
Lower Columbia Fish Enhancement Group
Volunteer Data Sheet
WATERSHED: Upper NF Lewis River

Date	Site Location	Species	No. Fish	Tails Cut	Whole/ Clipped	No. Volunteers	No. Hours Worked	Total Volunteer Hours
10-Oct	MRBS	Coho	94	Y	W	5	3	15
10-Oct	CCBS	Coho	94	Y	W	5	2	10
10-Oct	LLRF	Coho	94	Y	W	5	3	15
17-Oct	MRBS	Coho	234	Y	W	5	3	15
17-Oct	CCBS	Coho	233	Y	W	5	3	15
17-Oct	LLRF	Coho	234	Y	W	5	3	15
24-Oct	MRBS	Coho	214	Y	W	5	3	15
24-Oct	CCBS	Coho	214	Y	W	5	3	15
24-Oct	LLRF	Coho	214	Y	W	5	3	15
25-Oct	MRBS	Coho	76	Y	W	2	3	6
25-Oct	CCBS	Coho	75	Y	W	2	3	6
25-Oct	LLRF	Coho	76	Y	W	2	3	6

Site Location	Total
Clear Creek Bridge Site (CCBS)	**616**
Lower Lewis River Falls (Crab Cr. Bridge Site)(LLRF)	**616**
Muddy River Bridge Site (MRBS)	**618**
TOTAL	**1,850**

APPENDIX C

SWIFT RESERVOIR FLOATING SURFACE COLLECTOR SMOLT COLLECTION EFFICIENCY EVALUATION – 2019 FINAL REPORT

Comment Matrix: Swift FSC Collection Efficiency Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee December 6, 2019 .

Commenter	Comment Number	Location	Comment	Response
NOAA Fisheries, Josh Ashline	1	Section 1.3 Previous Studies, Page 2, line 135	I find it a little concerning that the FSC collection efficiency studies and reports are not being consistently done by the same organization/scientists. Each will have their own methods and as reported within the Four Peaks report, the methods have evolved significantly through time. This makes annual comparisons more difficult to without introducing bias. I regrettably have not read the previous reports, but personally endorse Four Peaks, the presentation yesterday was well done, as is this report.	Yes, but not concerning. Slight changes in methodologies and focus has been dictated in part by the information learned the previous year as well as assessing various modifications made annually to improve collection efficiency. (See Section 4.1 below - line 725). While adaptive management has driven this process, methodologies have remained consistent with the current Lewis River Monitoring and Evaluation Plan. Also the PacifiCorp lead scientist has remained the same since the first study year (2013).
NOAA Fisheries, Josh Ashline	2	Section 2.2.1 Tagging and Release, Page 6, line 200	To me it is unclear how the tagged population was originally collected. Are they captured in the FSC, tagged and re-released? So essentially working with non-naive juveniles? Or are they captured elsewhere using some unknown method. This needs to be clarified within section 2.2.1.	Yes. Juveniles were captured at the FSC, tagged, and then taken back upstream. They are non-naïve. From the text: *PacifiCorp collected fish for dual PIT and acoustic tagging <u>at the FSC</u> between March 26 and June 26, 2019.*
NOAA Fisheries, Josh Ashline	3	Section 3.2, Page 19, line 457	I'm really happy that the modifications to the FSC have resulted in the highest capture efficiencies to date. However, I must go on record stating that larger fish are rejecting the collector is a significant issue for NMFS, and recovery of ESA listed species in the North Fork Lewis River. Larger smolts have the highest probability of ocean survival, and the FSC is selecting for smaller juveniles. NMFS VSP parameters includes diversity, and the FSC selecting for smaller juveniles is limiting the diversity of reintroduction efforts.	Agreed. NMFS design specifications for the Swift FSC were for a capture velocity of 7 ft/sec within the fish channel. The Swift FSC is preforming at that rate. Larger smolts, particularly steelhead, have been shown to escape these velocities. PacifiCorp is working to improve the lower portion of the fish channel with shading to reduce the observed avoidance behavior in 2019. Future studies will help to determine whether this works or if other measures are needed.
NOAA Fisheries, Josh Ashline	4	Section 3.3.4, Page 33, line 612	On page 33 sentence "For example, a smaller Chinook Salmon.....that visit the collection channel later in the season" . This sentence spurred a thought that you should include water temperature monitoring within the FSC flow channel, and use Temp as a covariate for rejection analysis. It might be a metabolic response, that with warmer water the juveniles swimming ability is slightly better. As we know temp dictates the metabolism of fish. Just a thought.	Noted. We will consider this in future work.
NOAA Fisheries, Josh Ashline	5	Section 4.1, Page 36, line 687	Shameless plug for a citation of mine... On page 36 the authors say age data is not available. Myself and others from FWS in Alaska published a paper that accurately predicts juvenile ages based on fork lengths. Find a copy of that paper attached. It might prove useful for future analysis, if you want to include an age surrogate. (Sethi et al 2017 accurate ageing)	Noted. We will consider this in future work. Thanks!

Comment Matrix: Swift FSC Collection Efficiency Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee December 6, 2019 .

Commenter	Comment Number	Location	Comment	Response
NOAA Fisheries, Josh Ashline	6	Section 4.2, Page 39, line 795	I really appreciate the authors conclusions on shade/light and the potential to help lower the rejection rate of fish entering the FSC. Plausible next steps/modifications in my opinion. Increasing the water velocity above the burst swimming rate of juvenile steelhead (best swimmers) should also help in lowering the rejection rate for all species.	Shade and light are a good first start in this location. Increasing water velocity is tricky. The Swift FSC was designed to NMFS criteria for velocity gradients in the fish channel. Increasing velocity too fast over a short distance can create hydraulic barriers for fish and preclude passage. PacifiCorp will continue to evaluate fish behavior in the fish channel in 2020.
WDFW, Kale Bentley	1	Executive Summary, Page ES-1, line 1	I would be good to report the collection efficiency "performance target" somewhere in the Executive summary (i.e., highlighting that it was met in 2019). I realize that is not the sole purpose of this report but it does given the reported collection efficiencies some context and is ultimately what is driving this work.	The performance metric for juvenile collection efficiency at the FSC as stated in the Lewis River Settlement Agreement is 95%. The metric is further defined in the current Monitoring and Evaluation Plan (2017).
WDFW, Kale Bentley	2	Section 1.1, Page 1, line 90	I would consider moving Figure 4 (schematic of metrics) somewhere in this area as it is much easier to visualize what these metrics are measuring and how they are related to one another.	Noted. We will consider this in future reports.
WDFW, Kale Bentley	3	Section 1.1, Page 1, lines 94, 97, and 101	The use of downstream migrants is a bit confusing (change to fish)- unclear what the denominator is until I saw Figure 4).	Change made.
WDFW, Kale Bentley	4	Section 1.1, Page 1, lines 95 and 97	Addition of subsequently makes it more clear what the numerator is	Change made.
WDFW, Kale Bentley	5	Section 1.1, Page 1, line 102	Add (i.e., Pent X Pret)	Change made.
WDFW, Kale Bentley	6	Section 1.3, Page 3, line 157	At the head of the reservoir? Isn't Pce only calculated with fish that enter the ZOI?	In 2018, biotelemetry was not used; only fish tagged with PIT tags. During that year, S_{RES} was used as a surrogate for P_{CE}. S_{RES} is calculated as the number of fish captured over the total number released at the head of the reservoir. See *Lewis River Fish Passage Program 2018 Annual Report* for more clarity.
WDFW, Kale Bentley	7	Section 2.2.1 Tagging and Release, Page 6, line 200	I could be wrong but I thought in previous years study fish were collected from the Eagle Cliff smolt trap and only when sample sizes were small that FSC fish were used. Given the patterns seen in the Merwin ATE study (i.e., capture efficiency of naive fish >> non-naive fish), it seems possible that only using non-naive fish could be affecting the results. Regardless, it would be worth mentioning somewhere (in one or two sentences) the reasoning behind this choice - perhaps this has been discussed/evaluated in previous years.	Yes. In 2015 and 2016, attempts were made to collect test fish at the screw trap at Eagle Cliff. We also recognize the potential for the non-naïve effects here. Unfortunately, fish collected at Eagle Cliff are generally too small to acoustically tag, so there typically isn't enough of them when the CE study needs them. Since 2017, all fish are collected and tagged at FSC. Any non-naive bias (i.e., tagging, transport, and re-entry/re-capture) is assumed to be constant across those years.
WDFW, Kale Bentley	8	Section 2.2.2, Page 7, line 231, Figure 3., areas between NTS-09, NTS-10, and ZOI-08	What area is this considered? Based on the definition of Pret in section xx.xx, I think this is NTS. Either way, it would be helpful to add a delineation of this area to the map to help relate Figure 3, 4, and 5	Noted. We will consider this in future reports.

Comment Matrix: Swift FSC Collection Efficiency Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee December 6, 2019 .

Commenter	Comment Number	Location	Comment	Response
WDFW, Kale Bentley	9	Section 2.3, Page 9, line 307, Table 2.	The calculations in this table are presented in a straightforward manner. Nicely done. However, I don't see how estimates of uncertainty are calculated here or in the Appendix. While the point estimate is certainly the most important, the collection efficiency standard does include a precision goal. Therefore, the results should include an evaluation of the precision, which if nothing else in the short term, would tell you something about sample sizes needed for future years given the observed collection efficiencies (if a power analysis hasn't been conducted).	Noted. We will consider this in future reports.
WDFW, Kale Bentley	10	Section 2.3, Page 9, line 309, Table 2. Notes	Does this assume that the PIT arrays are 100% efficient?	Yes
WDFW, Kale Bentley	11	Section 2.3, Page 10, line 318, Figure 4.	I may not totally understand how all of these areas are labeled but it appears as though NTS is missing from this schematic. Based on my understanding, the NTS is before the attraction flow channel and part of the blue trapezoid. Given that NTS is used in the definition of the performance metrics, I would make sure it is part of this schematic.	Noted. The NTS is part of the FSC Attraction Flow Channel and is the first structure fish enter.
WDFW, Kale Bentley	12	Section 2.4.4, Page 12, line 383, Figure 5.	Similar to my comment above - I'm trying to understand how Figure 4 and Figure 5 match up to one another. Does the "FSC Attraction Flow Channel" consist of both the NTS and Collection Channel? Regardless, I would slightly edit either Figure 4 or 5 (or both) to make this subtly more clear. Also, it could help to label the acoustic receivers here so they could be matched in Figure 3 (if possible - maybe with the 2D positioning the two receivers on the right hand side are actually more than two).	Yes. Commented noted. Will revise in future documents.
WDFW, Kale Bentley	13	Section 3.1.1 Tagging and Release, Page 13, line 386	Similar to my following comment regarding sample sizes - it would be good to report in the methods section what the target sample size was for each species and where this number came from and in the results whether that sample target was met. Based on results shown in Figure 6, I'm guessing a "tagging curve" has been established. If so, it would be good to mention that. These details could be added to the Appendix "Study Methods".	Noted. Samples size were based on methodologies defined in Objective 2 of the current *Lewis River Aquatic Monitoring and Evaluation Plan* (2017).
WDFW, Kale Bentley	14	Section 3.1.1, Page 14, line 397	This seems like a high percentage of tags that failed. Any idea what happened? Regardless, it may be worth discussing this "result" a bit more and if nothing else comparing it to previous years. Will this impact the number of fish that will be tagged next year (i.e., do you need to tag more fish given such a high proportion of tags fail)?	Yes. They failed to activate. This should be an isolated incident. At the end of the day, the only metric that this truly effected was P_{RES} as discussed.

Comment Matrix: Swift FSC Collection Efficiency Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee December 6, 2019 .

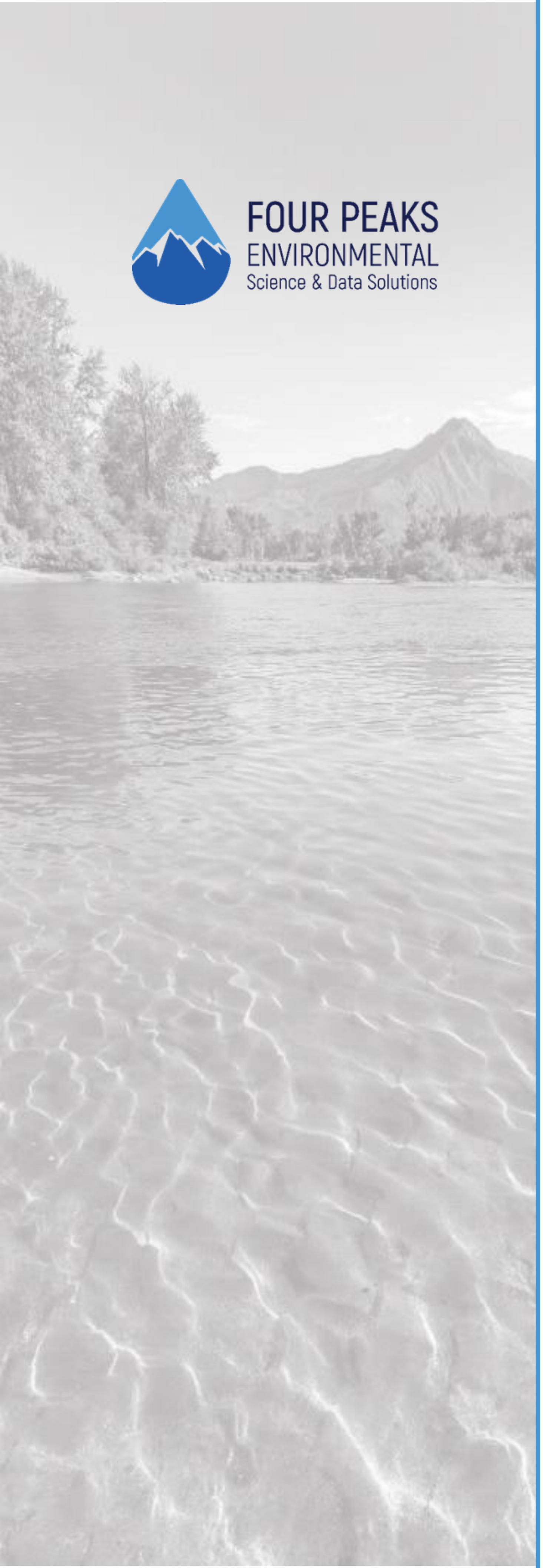
Commenter	Comment Number	Location	Comment	Response
WDFW, Kale Bentley	15	Section 3.1.1, Page 14, line 399	A little more context in regards to this statement would be helpful. For instance, was there some sort of power analysis or simulation conducted to determine the initial sample size and how a 26% reduction would affect inference? Similarly, If a power analysis has been conducted, it would be good to reference it. If not, where do the sample targets come from?	Samples size were originally based on methodologies defined in Objective 2 of the current Lewis River Aquatic Monitoring and Evaluation Plan (2017). Because of tag activation failure, the resulting sample sizes were smaller; however, sample size was sufficient to achieve a precision level of roughly +/- 10% at 90% confidence interval. As, stated this confidence interval was sufficient to draw comparisons with past results given the magnitude of the observed increases in passage metrics when compared to the results of earlier studies.
WDFW, Kale Bentley	16	Section 3.1.1, Page 14, line 405, Figure 6.	These plots are really useful to evaluate how representative the tags were in time. Would be helpful to see similar plots or summary stats for the size of fish tagged (i.e., used in the study) vs. not (or all fish) especially given the significance of size (reported in the results) to probability of recapture.	Noted. We will consider this in future reports.
WDFW, Kale Bentley	17	Section 3.1.4, Page 18, line 430	Is this because they were on fixed locations? Or rather, relatively fixed - assumed not to move?	Not sure what you are asking here. All hydrophones in the forebay were floating with geo-referencing GPS units attached. Statement in reports indicates that no interruption in beacon tag signals were detected.
WDFW, Kale Bentley	18	Section 3.1.4, Page 20, line 445, Figure 8.	ZOI-08 -- This is the only plot that stands out - would be good to provide a brief discussion in the section below as to why a fish's position being off by 20-30 m at this array did not have any adverse effects on the results. Given it's relative location (near the boundary between ZOI and NTS), I would think accuracy at this receiver would be important but maybe not.	As discussed in Section 3.1.4, position estimates at the boundary of the positioning array have lower accuracy than those closer to the center. ZOI-08 was positioned at the extreme Northwest corner of the array, which also placed the lead net between it and the other receivers in the ZOI array. These factors reduced the probability that the ZOI-08 beacon signal would be received by many other receivers, thus reducing accuracy for many of the estimates at this receiver. While accuracy at this receiver was relatively low, accuracy at the neighboring ZOI-07 receiver was much higher indicating that position estimate accuracy increased quickly as one moves away from the extreme Northwest corner of the array towards the center of the array. ZOI-08 and ZOI-07 both delineate the boundary of the ZOI and NTS zones suggesting that accuracy is generally much higher in this area than at the ZOI-08 location shown on the plot. Furthermore, ZOI-07 is positioned South of the lead net, the predominant direction from which fish approach the collector, indicating that the majority of approach vectors where reasonably accurate. That said, additional measures were taken to account for the potential of the lower accuracy at ZOI-08 to impact results. Additional filtering (discussed in section 2.3.3 and A6) was applied to determine presence in the NTS (which relied on a combination of position and amplitude). This increased the certainty that a given fish had entered the NTS and mitigated any bias caused by positional inaccuracy at the ZOI/NTS boundary. Position estimates at the ZOI/NTS boundary were used alone only for the analysis of fish behavior in the ZOI presented in 3.3.2 and 3.3.3, which is qualitative and thus less sensitive to the accuracy.
WDFW, Kale Bentley	19	Section 3.2, Page 23, line 477	I know you report the estimated percentage of inactive tags along with the total number released but it would be good to report the actual estimate number of inactive tags somewhere (here would be fine - point estimate with say 95% CI).	See Table 3 in the report

Comment Matrix: Swift FSC Collection Efficiency Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee December 6, 2019 .

Commenter	Comment Number	Location	Comment	Response
WDFW, Kale Bentley	20	Section 3.3.1, Page 26, line 500	Given the patterns seen in Figure 6, does this potentially suggest that estimates of collection efficiency could be biased high?	Efforts were made to closely match the distribution of releases with the run-at-large; however, natural variability in run size between season often confounds these efforts. We contend that there was good agreement between the acoustic tag sample releases and the run-at-large for Chinook and steelhead. However as shown in Figure 6, Coho appear to have all been released by the midpoint of the run. It is possible that this may have biased the Coho results relative to the run-at-large though it is not clear which direction the bias would be in if it is indeed present.
WDFW, Kale Bentley	21	Section 3.3.1, Page 26, line 518	I don't follow the logic in this sentence. Is peak collection based on the estimated number of fish collected at the FSC independent of the fish tagged in this study? What do you mean by "fish encountered during that time"?	Yes. Peak migration independent of tagging study.
WDFW, Kale Bentley	22	Section 3.3.4, Page 35, line 608	Perhaps initially referring to "at large" (not collected) fish here?	Noted
WDFW, Kale Bentley	23	Section 4.1, Page 39, line 640	I would explain this a bit more - I had to go back and look up what Sres was (reservoir survival) but still don't quite understand (without reading the report listed here) how this metric compares to Pce.	Noted. S_{RES} calculated as the total number captured over total number released. P_{CE} has a performance standard (98%), and is the total number captured over the total number detected in the Zone of Influence.
WDFW, Kale Bentley	24	Section 4.1, Page 43, line 663	Similar to previous comment, how is Sres comparable to Pce? Without further reading, I would think Sres would be the survival through the reservoir and not probability of capture (once the fish has survived reservoir passage and entered the ZOI).	See above response.
WDFW, Kale Bentley	25	Section 4.1, Page 45, line 690	Maybe I am missing something but this statement seems to contradict the information in paragraph two above this one that stated steelhead were larger in 2019 ("Steelhead in the run-at-large were also generally larger in 2019 than any other year "). Is the difference in statements due to the size comparison of study fish (tagged) vs. all fish captured at the FSC. If so, does that suggest that the tagged fish are not completely representative of the general population in terms of size?	Yes, the difference in statements is due to differences in the size distribution of the run-at-large and those that are selected for tagging. In past years, the size distribution of the run-at-large included a high proportion (>50%) of smaller fish (>200 mm). In 2019, these smaller fish were not present in any numbers.
WDFW, Kale Bentley	26	Section 4.1, Page 47, line 711	Are there timing differences between coho/Chinook and steelhead (e.g., steelhead arrive later when capture efficiencies are lower?). I wouldn't think so based on patterns seen at smolts traps in the lower Columbia Basin but perhaps worth mentioning to rule out that potential effect?	Yes
WDFW, Kale Bentley	27	Section 4.1, Page 47, line 713	Nice work teasing apart the pieces of Pce!	Noted
WDFW, Kale Bentley	28	Section 4.1, Page 47, line 725	This is awesome!	Noted
WDFW, Kale Bentley	29	Section 4.2, Page 47, line 762	Interesting	Noted

Comment Matrix: Swift FSC Collection Efficiency Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee December 6, 2019 .

Commenter	Comment Number	Location	Comment	Response
WDFW, Kale Bentley	30	Section 4.3 Conclusions, Page 49, line 798	Given everything that is discussed above, do you have any specific recommendations for either modifications to the "FSC" and/or evaluations for 2020 aimed at further increasing Pce (and really Pret)?	PacifiCorp is working with the Lewis River Aquatic Corrdination Committee (ACC) on potential modifcations with the fish channel to test in 2020.



SWIFT RESERVOIR FLOATING SURFACE COLLECTOR COLLECTION EFFICIENCY EVALUATION 2019 ANNUAL REPORT

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Appendices

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Acronyms, Initialisms, and Abbreviations

Acronym or Abbreviation	Defined
2004 Settlement Agreement	November 30, 2004 Settlement Agreement Concerning the Relicensing of the Lewis River Hydroelectric Projects – FERC Project Nos. 935, 2071, 2111, 2213, Cowlitz, Clark and Skamania Counties, Washington
2019 Study	2019 Swift Reservoir Floating Surface Collector Passage Evaluation
ATS	Advanced Telemetry Systems
CI	confidence interval
FERC	Federal Energy Regulatory Commission
FSC	floating surface collector
IQR	interquartile range
JSATS	Juvenile Salmon Acoustic Telemetry System
M&E Plan	Aquatic Monitoring and Evaluation Plan for the Lewis River (2017)
NTS	net transition structure
P_{CE}	collection efficiency
P_{ENC}	encounter rate
P_{ENT}	entrance efficiency
PIT	passive integrated transponder
P_{RES}	rate of reservoir passage
P_{RET}	retention efficiency
Project	PacifiCorp Swift No. 1 Project
ZOI	zone of influence

Executive Summary

The 2019 Swift Reservoir Floating Surface Collector Passage Evaluation (2019 Study) measured the collection efficiency of the Swift Floating Surface Collector (FSC) and assessed the behavior of juvenile salmonids released near the head of Swift Reservoir as they migrated downstream, approached, and interfaced with the Swift FSC. The primary purpose of the 2019 Study was to evaluate how recent modifications to the FSC have influenced collection efficiency (P_{CE}) and the overall effectiveness of the FSC. These modifications included (1) reducing operational noise by reprogramming the FSC pumps (Anchor QEA 2018) and adjusting baffles along the primary screens in the collection channel (R2 2019) to reduce vibration and decrease the risk of disturbing juvenile salmonid migrants in the vicinity of the FSC, and (2) increasing the attraction flow velocity at the entrance of the FSC to increase the likelihood of entraining juvenile salmonid migrants into the FSC. The modifications were performed in successive years with similar studies in 2017 before the modifications and in 2018 after the FSC pumps were reprogrammed but before the collection channel baffles were adjusted and attraction flow increased. The comparison of 2019 study results to those from these previous study years was used to evaluate the effectiveness of the modifications.

An array of eight acoustic receivers, called the zone of influence (ZOI) array, was installed in the Swift Dam forebay in front of the net transition structure (NTS). The NTS is the structure through which fish and water are funneled into the FSC collection channel. The ZOI array provided 2D position estimates of fish approaching the collector. Three additional receivers, DB North, DB Center, and DB South (collectively called the Swift forebay array), were installed at the entrance to the forebay to determine when acoustic tagged fish entered the Swift Dam forebay, and two receivers were installed to the rear of the NTS to aid in determining entrance and retention efficiency.

A total of 525 fish were dual passive integrated transponder and acoustic tagged and released between March 26 and June 26, 2019, to measure system performance and monitor fish behavior, including 155 Chinook Salmon, 300 Coho Salmon, and 70 steelhead. All study fish were released near Eagle Cliff at the upper end of Swift Reservoir. Although it was estimated that 26% of the acoustic tags used in the study failed to activate prior to release, the remaining active tags were sufficient to provide a meaningful comparison to results from past studies. Metrics for transition probabilities downstream of the Swift forebay were unimpacted and enabled accurate estimation of the rate of reservoir passage (P_{RES}).

In 2019, collection efficiency (P_{CE}) was 51% for Chinook Salmon and 64% for Coho Salmon, which were the highest recapture rates for those species of any study year to date. Collection efficiency for steelhead was 27%, which was marginally higher than steelhead P_{CE} observed in previous acoustic tagging studies. However, passive integrated transponder-only studies conducted in 2018 suggest that steelhead P_{CE} was significantly higher than in 2019. P_{RES} was similar to 2017, ranging from 63% for steelhead and Chinook Salmon to 86% for Coho Salmon.

The encounter rate (P_{ENC}) was high, ranging from 85% for Chinook Salmon to 95% for Coho Salmon. Entrance efficiency (P_{ENT}) of the FSC was also high, ranging from 78% for Chinook Salmon to 98% for Coho Salmon. Analysis of 2D fish tracks revealed that fish locate the FSC entrance shortly after entering the ZOI, and the highest density of fish positions in the ZOI was found to be immediately in front of and inside the NTS entrance. Although P_{ENC} was similar to 2017 results, 2019 P_{ENT} represents significant increases when compared to 2017 when fish were similarly positioned in the vicinity of the collector but failed to enter in large numbers. These results suggest that improvements made to the FSC since the 2017 study have been effective at encouraging fish to enter the NTS. However, only 60% of the fish that entered the NTS were collected (P_{RET}). Of the 279 fish of all three species that were tracked in the ZOI, 93% were detected inside the entrance of the NTS (P_{ENT}), but only 60% of the fish that entered the NTS were collected (P_{RET}). Fish that migrate through the reservoir are entering the collector but many are rejecting the collector once inside, suggesting the reach between the NTS and collection is the current bottleneck to achieving performance goals.

Species specific retention efficiency (P_{RET}) was variable, ranging from 28% for steelhead and 65% for Chinook and Coho salmon. Though 2019 P_{RET} represents further gains for Chinook and Coho salmon, steelhead P_{RET} was lower than in 2017. When taken in light of increased steelhead collection probability in 2018, these results indicate that the operational changes made after the 2018 study may have had varying effects on P_{RET}.

Acoustic telemetry data collected during the study enabled the analysis of fine scale movements in the collector, namely identifying when fish entered and exited the collection channel—the passage through which fish must travel between the NTS and the FSC. Multivariate analysis using these data revealed that larger fish were most likely to reject the collector after traveling as far as the collection channel. Given the fact that all species experienced the same collection environment but larger fish were significantly more likely to reject collection suggests that flow velocities within the collection channel have an asymmetric impact on fish of different sizes that may be independent of species. This “size effect” may be explained by larger fish being able to achieve burst velocities great enough to escape entrainment flows within the collector, and thus being able to make multiple visits and avoid collection. This may explain why steelhead P_{RET} declined at the same time that Chinook and Coho salmon P_{RET} increased: test steelhead were generally larger than other test fish and while increased attraction velocity encouraged fish of all sizes to enter the collector, larger fish were able to escape when faced with a condition that elicited an avoidance response. Finer scale observations are required to determine the location where fish are turning around.

Although diel period was not related to rejection within the collection channel, Chinook Salmon were collected predominantly at night (87% of Chinook Salmon study fish were collected at night). This was more varied for Coho Salmon and steelhead with higher percentages of fish collected during the day. Past research has found that accelerating flow field avoidance behavior is related to light levels with avoidance behavior increased with light and decreased when it was dark. These results suggest that some form of shading may be effective at decreasing rejection within the collector and thus further improve collection.

1 Introduction

1.1 Study Purpose and Objectives

The 2019 Swift Reservoir Floating Surface Collector Passage Evaluation (2019 Study) was conducted to collect and analyze data that informs decisions related to the operation and performance of the floating surface collector (FSC) relative to multiple performance metrics.

The primary purpose of the 2019 Study was to evaluate how the following recent modifications to the FSC and forebay environment have influenced collection efficiency (P_{CE}) and the overall effectiveness of the FSC:

- Reprogramming the FSC pumps to reduce vibration and decrease the risk of disturbing juvenile salmonid migrants in the vicinity of the FSC (Anchor QEA 2018)
- Adjusting baffles along the primary screens in the collection channel to further reduce vibrations that could disturb juvenile salmonids (R2 2019)
- Increasing the attraction flow velocity at the mouth of the collector to increase the likelihood of entraining juvenile salmonid migrants into the FSC by raising the floor of the Net Transition Structure (NTS) to reduce the cross-sectional area and increase attraction water velocity from 0.5 ft/s to 1.4 ft/s through the entrance of the NTS

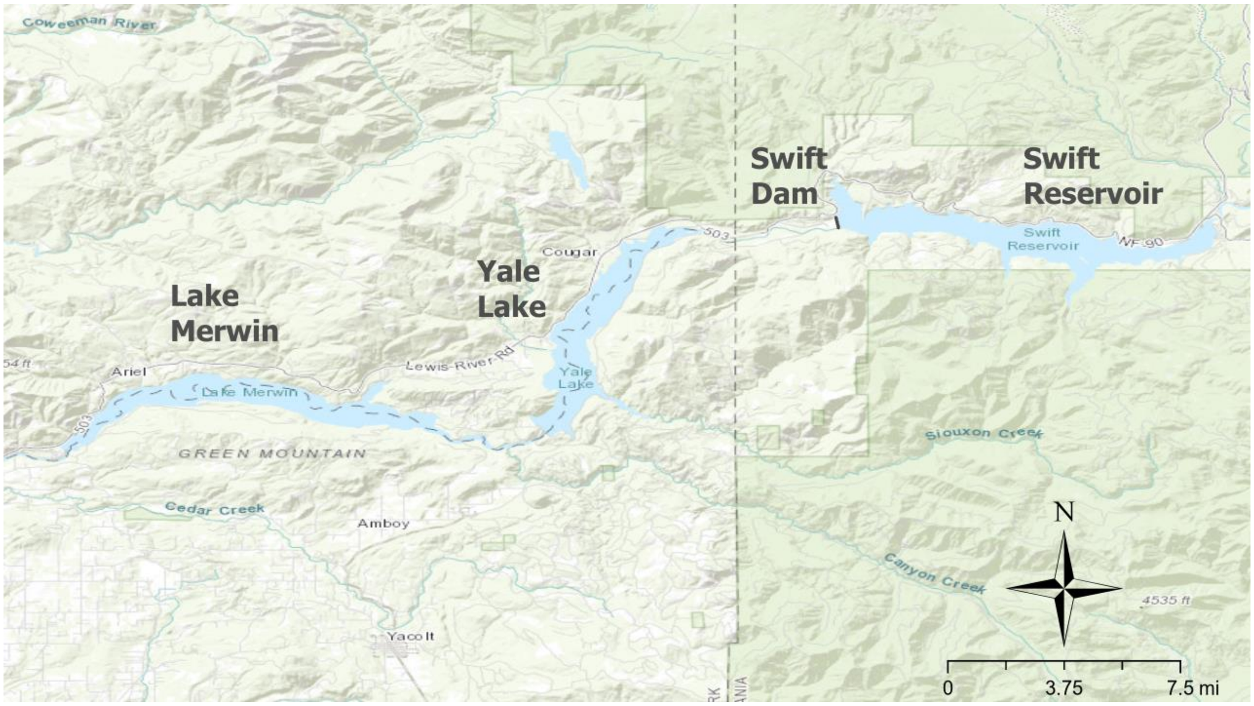
The performance of the modified FSC was evaluated and compared to previous years of study using the following metrics:

- Estimated rate of reservoir passage—the proportion of smolts released at the eastern end of Swift Reservoir, near Eagle Cliff, that migrate to the forebay of Swift Dam (P_{RES})
- Estimated encounter rate (P_{ENC})—the proportion of fish that enter the FSC forebay and are subsequently detected in the FSC flow net attraction area immediately outside the Swift FSC, defined as the zone of influence (ZOI)
- Estimated entrance efficiency (P_{ENT})—the proportion of fish that enter the ZOI and subsequently enter the NTS
- Estimated retention efficiency (P_{RET})—the proportion of fish that enter the NTS that are successfully collected
- Estimated collection efficiency (P_{CE})—the proportion of fish that enter the ZOI and successfully pass into the FSC and are collected (i.e., Pent X Pret)
- Monitored behavior of downstream migrants in the forebay of Swift Reservoir, specifically in relation to the lead and guide nets, entrance of the FSC, and within the collection channel

To obtain estimates for each metric, juvenile salmonids were dual passive integrated transponder (PIT)- and acoustic-tagged then released near the head of the Swift Reservoir and their behavior was subsequently monitored as they approached, interacted with, and were potentially collected in the FSC.

1.2 Background

The PacifiCorp Swift No. 1 Project (Federal Energy Regulatory Commission [FERC] Project No. 2111; [Project]) is the furthest upstream and largest hydroelectric project in the Lewis River system (**Error! Reference source not found.**). The Project consists of Swift Dam, which is a 412-foot-high by 2,100-foot-long embankment dam that impounds a 4,600-acre reservoir known as Swift Reservoir.



Spatial Reference: GCS WGS 1984; Aerial imagery source: ESRI, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, ESRI Japan, METI, ESRI China (Hong Kong), OpenStreetMap contributors, and the GIS User Community

Figure 1. Vicinity map of the Swift Reservoir and Swift Dam on the Lewis River

In 2008, the Project was issued a new FERC license (FERC 2008) that includes provisions for restoring anadromous salmonids to the Lewis River Basin. As a component of the overall restoration goal, the license incorporates specific measures from the November 30, 2004 Settlement Agreement Concerning the Relicensing of the Lewis River Hydroelectric Projects – FERC Project Nos. 935, 2071, 2111, 2213, Cowlitz, Clark and Skamania Counties, Washington (2004 Settlement Agreement) including the construction and operation of a modular FSC at the lower end of Swift Reservoir near Swift Dam to collect migrating juvenile salmonids for subsequent transportation downstream of the Project. In addition, the 2004 Settlement Agreement requires monitoring and evaluation of the P_{CE} at the FSC, and the subsequent Aquatic Monitoring and Evaluation Plan for the Lewis River (M&E Plan) has identified a P_{CE} performance target of 95% at a 0.05 precision level for the FSC (PacifiCorp and CPUD 2017). For the purposes of the M&E Plan and the 2019 Study, P_{CE} is defined as the proportion of juvenile anadromous fish of each of the species designated in the 2004 Settlement Agreement[1] that is available for collection and is actually collected.

1.3 Previous Studies

Since 2013, the performance of the FSC has been evaluated using radio telemetry, PIT, and combined PIT and acoustic telemetry methodologies (Courter et al. 2013; Stroud et al. 2014; Reynolds et al. 2015;

[1] Species designated in Section 4.1.7 of the 2004 Settlement Agreement are spring-run Chinook Salmon, winter steelhead, Coho Salmon, Bull Trout, and sea run Cutthroat Trout.

Caldwell et al. 2016; Anchor QEA 2018; PacifiCorp and CPUD 2019). Although there has been considerable variation in study design and year-to-year results, several trends have emerged from these studies. Most importantly, observed P_{CE} for all species tested has been consistently lower than the 95% performance target in all years and ranged from 7% (Courter et al. 2013) to 29% (Caldwell et al. 2016; Table 1) for combined test species. Chinook Salmon have had the lowest P_{CE} among the species tested and were not recaptured in the FSC in many of the previous study years.

Although P_{CE} estimates were below the target in previous years, these same studies also demonstrated that comparatively high percentages of fish were successfully transiting the length of Swift Reservoir to the ZOI and were therefore coming in relatively close proximity to the FSC (Table 1; Reynolds et al. 2015; Caldwell et al. 2016; Anchor QEA 2018). The occurrence of fish migrating to, but not being successfully collected within the FSC, provided a logical path for considering “near-field” modifications to the FSC and associated structures that would either improve guidance to or attractiveness of the FSC entrance to potential migrants.

Accordingly, a series of modifications were made to improve the collection performance of the FSC, and these appear to have influenced P_{CE}. In 2016, increases in P_{CE} were associated with installation of a fish lead net in front of the FSC. Acoustic telemetry studies in 2017 showed that the lead net was effective at directing fish towards the entrance of the FSC; however, significant numbers failed to enter. In late 2017, FSC sorting area flow pumps were reprogrammed in an effort to reduce vibrations that may have deterred smolts from entering the FSC (PacifiCorp and CPUD 2019). PIT tag studies conducted in 2018 showed significant increases in the proportion of fish released at the head of the reservoir that are ultimately collected suggesting that pump modifications may have further increased P_{CE} (PacifiCorp and CPUD 2019).

In addition to the performance of the FSC itself, previous studies also suggested several other factors may influence FSC performance metric estimates or interpretations thereof including the origin of fish used in tagging studies (Stroud et al. 2014) and post-release overwintering behavior by juvenile salmonids (Caldwell et. al 2016). These factors are not evaluated in the 2019 Study but are discussed in Anchor QEA 2018.

Table 1. Summary of results from previous Swift floating surface collector collection efficiency studies conducted between 2013 and 2018

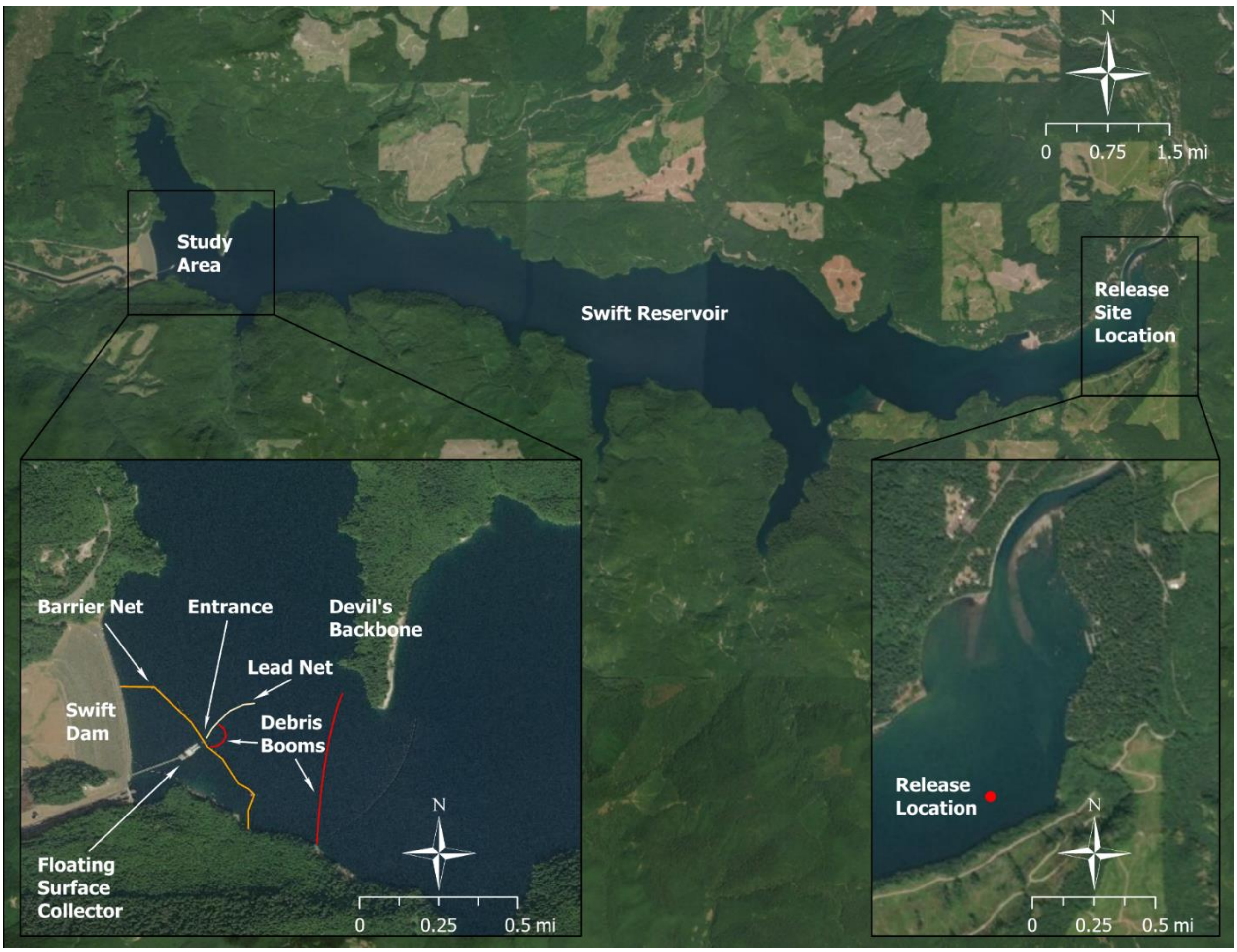
Study Attributes						Detection Numbers (Total)			Detection Estimates (Total)[1]				
Year	Study Type	Capture Location	Release Location	Species	Release Numbers	Detected Forebay	Detected ZOI	Captured at FSC	P_{RES} Estimate (%)	ZOI Detection Rate (%)	P_{ENT} Estimate (%)	P_{RET} Estimate (%)	P_{CE} Estimate (%)
2013	Radio Telemetry	FSC	<3.1 miles east of FSC	Chinook Salmon	58	NA	46	0	NA	79.3	NA	NA	0.0
				Coho Salmon	82	NA	44	6	NA	53.7	NA	NA	6.0
				Steelhead	NA	NA	NA	NA	NA	NA	NA	NA	NA
2014	Radio Telemetry	FSC	2 miles east of FSC	Chinook Salmon	20	NA	3	0	NA	15.0	NA	NA	0.0
				Coho Salmon	157	NA	31	9	NA	19.7	NA	NA	29.0
				Steelhead	16	NA	4	1	NA	25.0	NA	NA	25.0
2015	Dual PIT/ Acoustic Telemetry	Eagle Cliff Rotary Screw Trap/Hook and Line	Eagle Cliff	Chinook Salmon	14	9	6	0	64.3	42.9	NA	NA	0.0
				Coho Salmon	139	126	110	13	90.6	79.1	NA	NA	11.8
				Steelhead	47	43	43	8	91.5	91.5	NA	NA	18.6
2016	Dual PIT/ Acoustic Telemetry	FSC and Eagle Cliff Rotary Screw Trap	Eagle Cliff	Chinook Salmon	3	1	1	0	33.3	33.3	NA	NA	0.0
				Coho Salmon	156	140	98	30	89.7	62.8	NA	NA	30.6
				Steelhead	40	28	17	4	70.0	42.5	NA	NA	23.5
2017	Dual PIT/ Acoustic Telemetry	FSC	Eagle Cliff	Chinook Salmon	108	75	62	7	69.4	82.7	46.8	24.1	11.3
				Coho Salmon	232	184	164	46	81.0	91.6	65.1	41.1	26.7
				Steelhead	180	117	107	21	66.7	89.2	48.6	40.4	19.7
2018	PIT	FSC	Eagle Cliff	Chinook Salmon	396	--	--	94	--	--	NA	NA	23.7[2]
				Coho Salmon	484	--	--	191	--	--	NA	NA	39.5[2]
				Steelhead	278	--	--	136	--	--	NA	NA	48.9[2]

Notes:
Source: Courter et al. 2013; Stroud et al. 2014; Reynolds et al. 2015; Caldwell et al. 2016; Anchor QEA 2018; PacifiCorp and CPUD 2019
1. For 2013 through 2017, seasonal performance metrics have been corrected for array detection efficiency.
2. In 2018, survival probability through reservoir (S_{RES}) was used as a surrogate for collection efficiency.
-- = not calculated
NA = not applicable

2 Methods

2.1 Study Location and Timing

The 2019 Study examined the behavior of dual PIT- and acoustic-tagged fish released near the head of Swift Reservoir and their fine-scale movements near the FSC adjacent to Swift Dam. The FSC is a floating barge that captures migrating juvenile salmonids at the surface of the reservoir. Fish are guided to the FSC by the FSC's attraction flows and by the barrier and lead nets (**Error! Reference source not found.**). Fish enter the FSC via the NTS, which funnels water and fish into an artificial stream channel (termed the "collection channel" herein). The collection channel entrains and guides fish from the NTS 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. Debris booms are in place to limit the accumulation of logs and other debris in the FSC entrance.



Spatial Reference: GCS WGS 1984; Aerial imagery source: ESRI DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGrid, IGN, and the GIS User Community

Figure 2. Vicinity map of the floating surface collector and release area for tagged fish within Swift Reservoir

The release location for tagged fish is approximately 9 miles upstream from the FSC along the south shore opposite the Swift Forest Camp at the eastern end of the Swift Reservoir (**Error! Reference source not found.**). Study fish were released between March 26 and June 26, 2019. Receivers were removed from the water on July 22, 2019, the same day on which the collector was shut down for the summer maintenance period. A few study fish were still being detected on the ZOI array on July 22, 2019; however, daily catch rates at the FSC had decreased below the level at which the collector could be shut down for summer maintenance (PacifiCorp 2015). The period from first release (March 26) to last detection in the ZOI (July 22) is considered the study period.

2.2 Telemetry

Dual PIT- and acoustic-tagged fish were used to evaluate fish behavior as these fish were tracked through the reservoir and into the FSC.

2.2.1 Tagging and Release

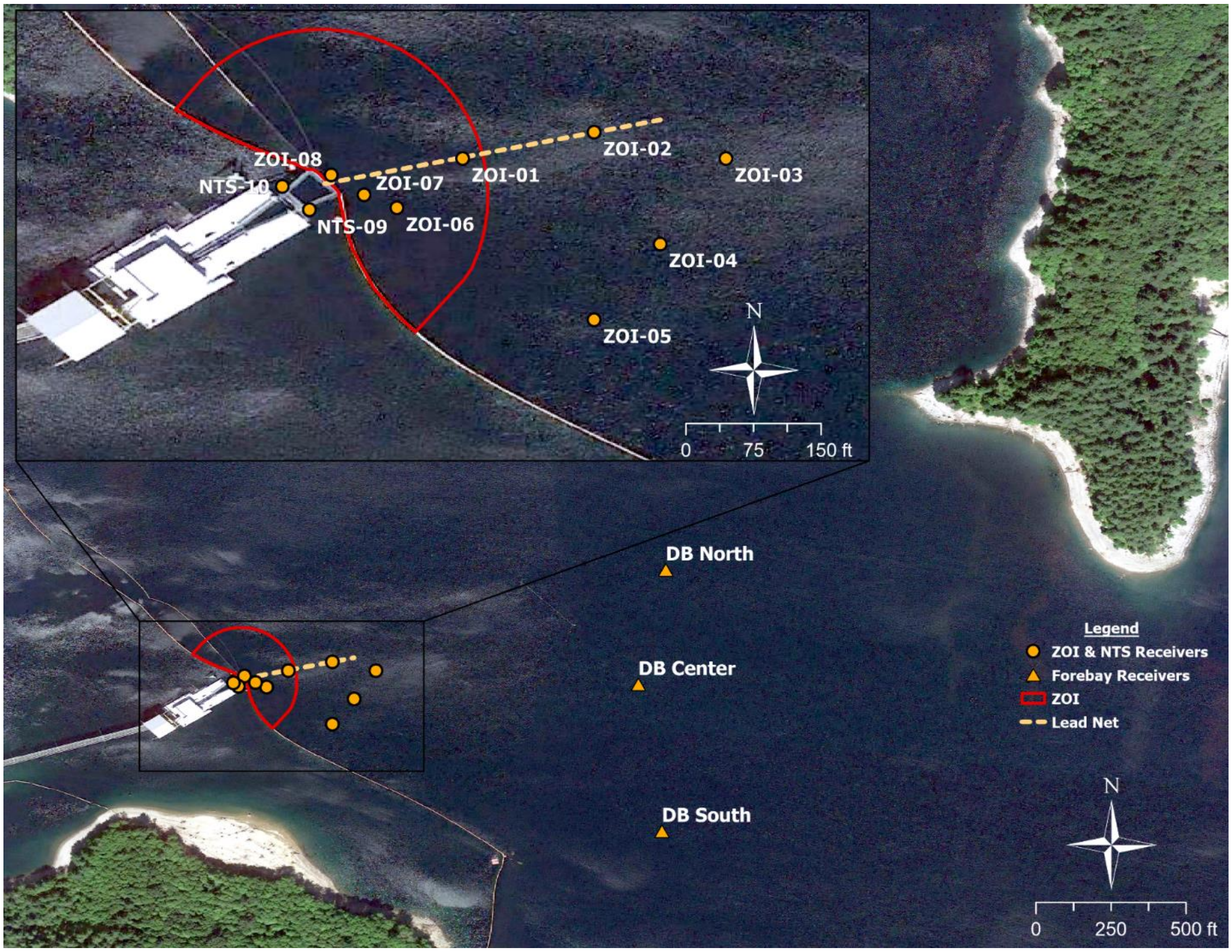
PacifiCorp collected fish for dual PIT and acoustic tagging at the FSC between March 26 and June 26, 2019. After collection, each fish was anesthetized with MS-222 (Tricaine methanesulfonate) and surgically implanted with an Advanced Telemetry Systems (ATS) SS400 acoustic transmitter (median dimensions 15.0 x 3.23 mm; 215 mg) and a Biomark 12.5 mm, 134.2 kilohertz ISO FDX-B PIT tag using the methodology described in Reynolds et al. (2015). The SS400 acoustic transmitters were pre-set to emit an acoustic signal every 3 seconds. Following tagging, fish were transported by boat to the Eagle Cliff release site at the eastern end of Swift Reservoir (**Error! Reference source not found.**) where they were subsequently released. PIT tags were scanned using an HPR Plus reader after implantation and uploaded to PTAGIS using P4 software with associated information on species, length, and paired acoustic tag code.

2.2.2 Detection and Recapture

An array of eight ATS Juvenile Salmon Acoustic Telemetry System (JSATS) Model SR3017 acoustic receivers were installed in the area in front of the NTS (**Error! Reference source not found.** inset) for detection and tracking of acoustic-tagged fish approaching the NTS (hereafter referred as ZOI array). The ZOI array is capable of providing the information necessary for estimating the 2D position of study fish within the ZOI. The general placement of the ZOI array is intended to track fish approaching the FSC primarily from the south and was based on historical fish movement patterns and the general propensity of fish to approach the ZOI from the south shoreline and enter the ZOI on the south side of the lead net.

Two additional SR3017 receivers were deployed along side of the NTS (Figure 3 inset) to provide data to determine when fish enter the NTS (hereafter referred as the NTS array). Three ATS SR3001 presence-absence receivers (DB North, DB Central, and DB South) were installed near Devil's Backbone at the entrance to the Swift Dam forebay, called the Swift forebay array, in a north-south orientation to detect fish entering the Swift Dam forebay (Figure 3).

The ZOI array configuration was designed through a combination of computer simulation and field testing. The computer simulation was used to initially develop an optimal array configuration that was likely to provide the greatest coverage within the ZOI while also minimizing the error in position estimates. The optimal configuration was refined at the time of deployment through the use of test tags to reflect additional site constraints that could not be incorporated at the time of the computer simulations (Section 2.2.3).



Spatial Reference: GCS WGS 1984; Aerial imagery source: Google Earth (v7.3.2.5776, imaged July 25, 2018)

Figure 3. Map of western edge of Swift Reservoir, including Swift forebay array; (inset) Swift Dam zone of influence with floating surface collector, lead net, barrier net structures and locations of acoustic receivers

Receivers in the ZOI and NTS arrays were equipped with GPS to maintain time synchronization and provide continuous receiver position data, both important factors in obtaining accurate fish position estimates from acoustic telemetry. Receivers in the ZOI array were also equipped with 60-second interval beacon tags. The beacon tags were used as a continual check that receivers in the array were functioning properly and as a backup method for maintaining time synchronization in instances where the GPS lost satellite link. Two additional beacons were deployed within the NTS to assist in evaluating detection efficiency and troubleshooting potential issues within the NTS region. Additional details of the acoustic receiver deployment are available in Appendix A. PIT detections for the 2019 Study occurred on two antennas within the FSC as fish passed over the sorting bars and through flumes leading to the collection tanks. Automated PIT-tag detection at these locations occurred via two Biomark IS1001 (firmware version 1.6.1) antennas, known as the Sorting Rack and Port/Starboard Smolt Flume

Antennas. Fish entering the FSC are shunted to either the port or starboard side of the collector, and thus, detection can occur on only one of the smolt flume antennas. All antennas emit hourly test tag codes which were regularly monitored to ensure the antennas maintained high detection efficiency and did not experience malfunctions during the study season. Detections occurring at PIT-tag antennas were automatically uploaded to PTAGIS multiple times a day via an internet connection.

Detection efficiency was estimated for a given array by evaluating how many fish were confirmed to be downstream of the array and of those, how many were detected at the array in question. Detection efficiency of the PIT array (the most downstream detection point) was assumed to be 100%. For example, if 100 fish were observed downstream of the Swift forebay array (i.e., at any combination of ZOI, NTS, or PIT arrays) and 95 of those were also observed at the Swift forebay array, then the detection efficiency of the Swift forebay array would be estimated at 95%.

2.2.3 Acoustic Receiver Range Estimation

A boat drag of acoustic test tags was conducted in the area of the ZOI receivers (ZOI-01 through ZOI-06) to determine detection range and to test positioning accuracy. The range test consisted of discrete static point measurements distributed inside the estimated detection range of this group of receivers. During these tests (completed on February 19 and 20, 2019, after initial deployment), tags were held at 1.5-meter and 4.5-meter depths for approximately 2 minutes each, and corresponding positions were recorded with a handheld GPS unit. Additional range tests were conducted at fixed locations inside the NTS shortly after deployment, as well as after the final configuration change for the NTS, on April 2. For these tests, beacons were also deployed at 1.5- and 4.5-meter depths for 5 minutes, and positions recorded with handheld GPS units.

Range testing was not conducted at the presence-absence receivers in 2019. Instead, detections from beacon tags fitted to each presence-absence receiver were used to estimate and confirm detection range on this array throughout the season.

2.2.4 Data Processing and Quality Control

Raw detection data were downloaded from the receivers on an approximately bi-weekly schedule and backed-up to secure cloud-based storage. After downloading data from each receiver, a new formatted memory card was placed in the receiver. Only after ensuring backup of the data were the memory cards reformatted. In addition, the internal clocks of the three autonomous receivers located at the Devil's Backbone (i.e., the Swift forebay array) were re-synchronized after each download event prior to redeployment of the receivers.

Detection data were checked after each data download event to ensure corrupt records were removed, beacon tags on adjacent receivers were detected, and estimated receiver positions were consistent with deployment information. Data were then filtered to remove multipath and false positive signals using methods described in Weiland et al. (2009). To be accepted as a valid tag detection, an acoustic tag had to be detected at least six times in 60 seconds on a receiver.

2.2.5 Position Estimates

Positions of test fish were estimated based on the difference in the time of arrival of each ping at the ZOI array. The positioning approach follows the concepts outlined in Deng et al. (2011). The solution methodology relies on successively refining estimated positions to minimize the difference between the estimated time difference of arrivals and the observed time difference of arrival. While 3D positions were estimated, the metrics evaluated in this report did not require the use of depth information because the X and Y positions were sufficient to assess presence of test fish within the ZOI. Further details on the positioning algorithm are provided in Appendix A.

The positioning algorithm was run throughout the season on each batch of acoustic detection data retrieved from the field after processing (as described in Section 2.2.4). These in-season results formed the basis of calculating the in-season performance metrics and provided an opportunity to review results in-season and identify refinements to data processing routines that improved tracking efficiency. Once final refinements to the data processing routines were made, all previously processed data were reprocessed to obtain the final position estimates used in this report.

2.3 Performance Metrics

The key performance metrics for the 2019 Study included P_{RES}, P_{ENC}, P_{ENT}, P_{RET}, and P_{CE} (Table 2; Figure 5). The metrics are proportions where the denominators are the number of fish released, detected in the entrance to the forebay, detected in the ZOI, or detected in the entrance to the NTS, respectively. Correction factors are applied to these proportions to account for receiver detection efficiency. In general, each "uncorrected" detection metric is calculated using observed detection numbers and then a correction factor is applied as shown in Table 2 to obtain the final "corrected" value. Seasonal estimates of performance using corrected values are reported in this annual report. Periodic estimates of performance using uncorrected values were provided throughout the fish passage season to PacifiCorp to allow FSC performance and implementation of the 2019 Study to be tracked. Discussion of how individual metrics were calculated is provided below. Further details on the metric calculation methods are available in Appendix A.

Table 2. Calculations for uncorrected and corrected performance metrics

Metric	Calculation (uncorrected)	Calculation (corrected)
Rate of Reservoir Passage (P_{RES})	$P_{RES} = \frac{DET_{Swift}}{R}$	$\hat{P}_{RES} = \frac{(C/R)}{P_{ENC} \cdot P_{ENT} \cdot P_{RET}}$
Encounter Rate (P_{ENC})	$P_{ENC} = \frac{DET_{ZOI}}{DET_{Swift}}$	$\hat{P}_{ENC} = \frac{(DET_{ZOI}/D_{EFF-ZOI})}{DET_{Swift}}$
Entrance Efficiency (P_{ENT})	$P_{ENT} = \frac{DET_{ENT}}{DET_{ZOI}}$	$\hat{P}_{ENT} = \frac{(DET_{ENT}/D_{EFF-ENT})}{(DET_{ZOI}/D_{EFF-ZOI})}$
Retention Efficiency (P_{RET})	$P_{RET} = \frac{C}{DET_{ENT}}$	$\hat{P}_{RET} = \frac{C}{(DET_{ENT}/D_{EFF-ENT})}$
Collection Efficiency (P_{CE})	$P_{CE} = \frac{C}{DET_{ZOI}}$	$\hat{P}_{CE} = \frac{C}{(D_{ZOI}/D_{EFF-ZOI})}$

Notes:
C = number of unique tagged fish identified at the PIT arrays inside the FSC (i.e., collected)
$D_{EFF-ENT}$ = detection efficiency of the NTS array
$D_{EFF-ZOI}$ = detection efficiency of the ZOI array
DET_{ENT} = number of tagged fish detected inside the entrance of the NTS using acoustic telemetry
DET_{Swift} = number of juveniles detected entering Swift Dam forebay (i.e., at any acoustic receiver in Swift forebay array)
DET_{ZOI} = number of unique tagged fish tracked in the vicinity of the FSC (i.e., in the ZOI) using acoustic telemetry
R = number of unique tagged fish released

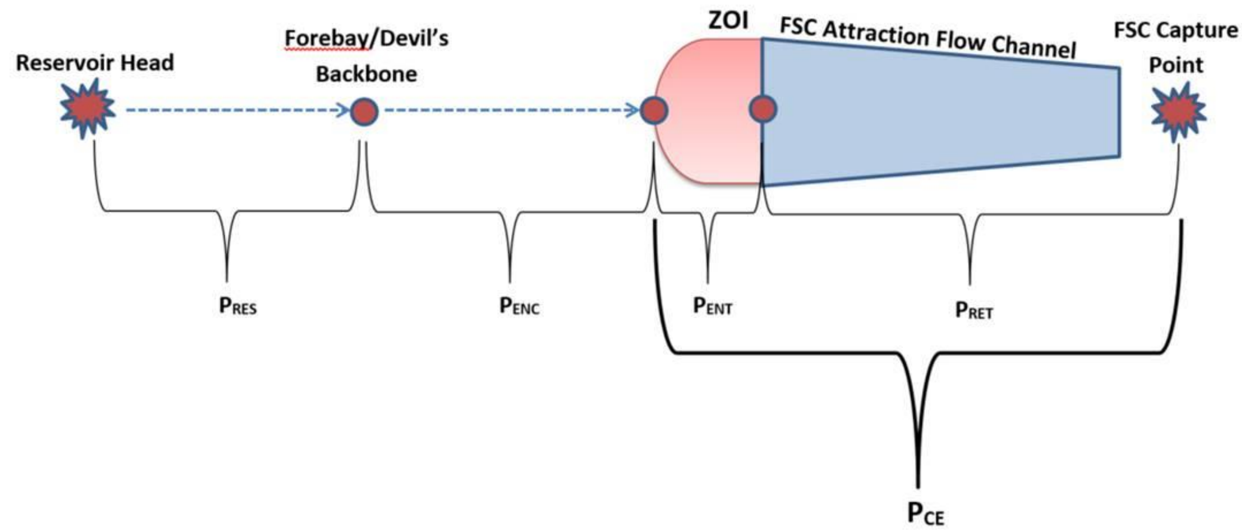


Figure 4. Performance metric schematic

2.3.1 Rate of Reservoir Passage

The rate of reservoir passage (P_{RES}) is an estimate of the proportion of study fish that are released at Eagle Cliff and encounter the Swift forebay array by passing either the north, central, or south receivers (i.e., DB North, DB Center, or DB South).

2.3.2 Encounter Rate

The encounter rate (P_{ENC}) is an estimate of the proportion of study fish detected in the forebay that locate and enter the ZOI. Fish were determined to have entered the ZOI based on their estimated 2D (X,Y) positions and a filter that accounted for the possible presence of spurious position estimates (see Appendix A).

2.3.3 Entrance Efficiency

Entrance efficiency (P_{ENT}) is an estimate of the proportion of fish tracked through the ZOI that enter the NTS. Fish were determined to have entered the NTS based on 2D position estimates and a filter that examined acoustic signals at receivers positioned towards the rear of the NTS (NTS-09 and NTS-10; Figure 3**Error! Reference source not found.**). Additional details of the process used to examine acoustic signals to confirm presence in the NTS are provided in Appendix A.

2.3.4 Retention Efficiency

Retention efficiency (P_{RET}) is the proportion of fish that enter the NTS that are ultimately collected. Fish were determined to have been collected based on PIT detection on the antennas at the sorting rack and collection flume (Section 2.2.2).

2.3.5 Collection Efficiency

Collection efficiency (P_{CE}) is an estimate of the proportion of downstream migrants that enter the ZOI, successfully pass into the FSC, and are collected.

2.4 Behavioral Analysis

Several analyses were conducted using data obtained during the 2019 Study to evaluate the behavior of downstream migrants in the forebay of Swift Reservoir, specifically in relation to the lead and barrier nets, entrance of the FSC, and within the collection channel.

2.4.1 Time of Arrival

Time of first arrival in the ZOI was evaluated to assess whether seasonal or diel timing was related to collection events. Seasonal timing was assessed using logistic regression, where the binomial response of collection status (yes or no) was regressed against travel time and day of year. A whole model test was used to examine whether either continuous variables predicted collection better than constant response probabilities. Diel timing of collection rates was evaluated by categorizing the hour of day that study fish entered the ZOI and collector into daytime (0500-2100 hours) or nighttime (2100-0500 hours). The probability of collection across each portion of the day was tested for differences using likelihood ratios and a Pearson Chi-square test. All three analyses were completed for each species.

2.4.2 Fish Position

A heat map of all data points was generated to show the general position of fish within the area monitored by the ZOI and NTS arrays by performing a 2D point density estimate and displaying the resulting contours (Section 3.3.2). This analysis was conducted in ArcGIS software using point density analysis routines (ESRI 2011). Plots were created for each species studied with additional plots created for collected versus non-collected fish to evaluate whether there was any spatial difference between the two groups.

2.4.3 Arrival and FSC Approach Direction

The direction from which fish entered the ZOI was examined by creating point density maps of position estimates within 30 minutes after the fish first entered the ZOI. Plots were created for each species and for collected vs. not-collected fish. Collector approach was examined similarly by creating density plots of the positions within 30 minutes before the fish entered the NTS immediately before collection or exited the ZOI for the final time. These results were used to evaluate whether fish were approaching the collector predominantly along the lead net, barrier nets, or without guidance from either net. Point density was computed using the same methods described in Section 2.4.2 above.

2.4.4 Rejection Inside the Collector

The probability of a fish exiting the collector after entering the collection channel was calculated across species, time of day, and week of year to examine differences in rejection rates among species and throughout the season.

For zones within the FSC (Figure 5), the times at which fish were present within a given zone was determined using a combination of evidence including position estimates, pattern of detections on the receivers in the NTS and ZOI arrays (Figure 3), and the record of PIT detections in the collector. These data formed the basis for a multivariate analysis of behavior within the collection channel with variables that included length, species, number of discrete visits to the collection channel, diel period of visits, release week, and last week detected in the collection channel (which was used to distinguish fish that were at large later in the season).

Additional details of how these data were processed and used to determine extent of entry into the FSC are provided in Appendix A.

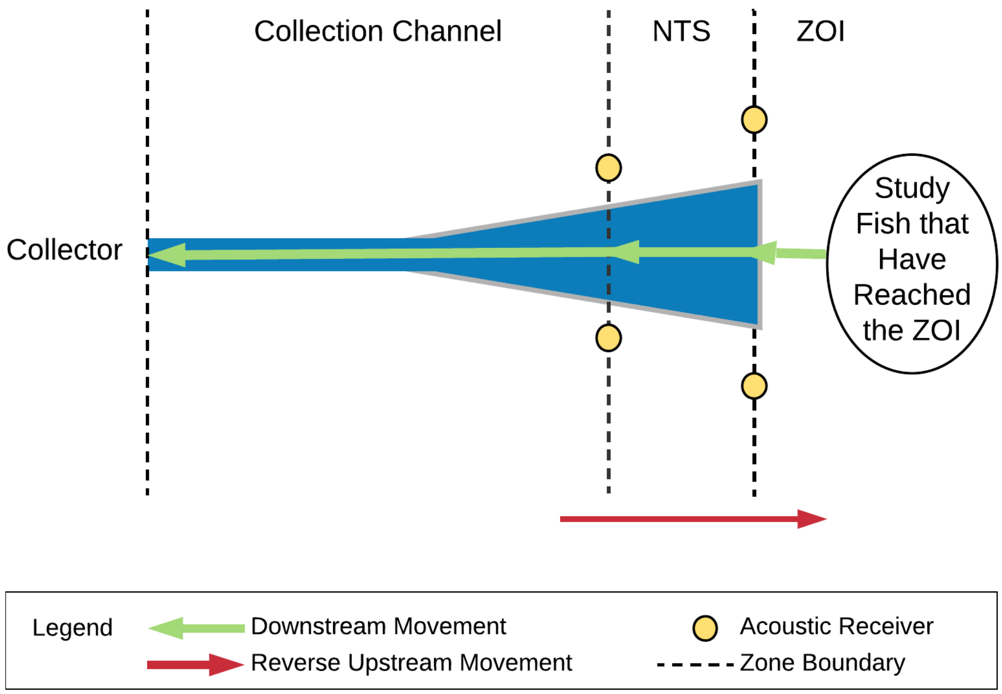


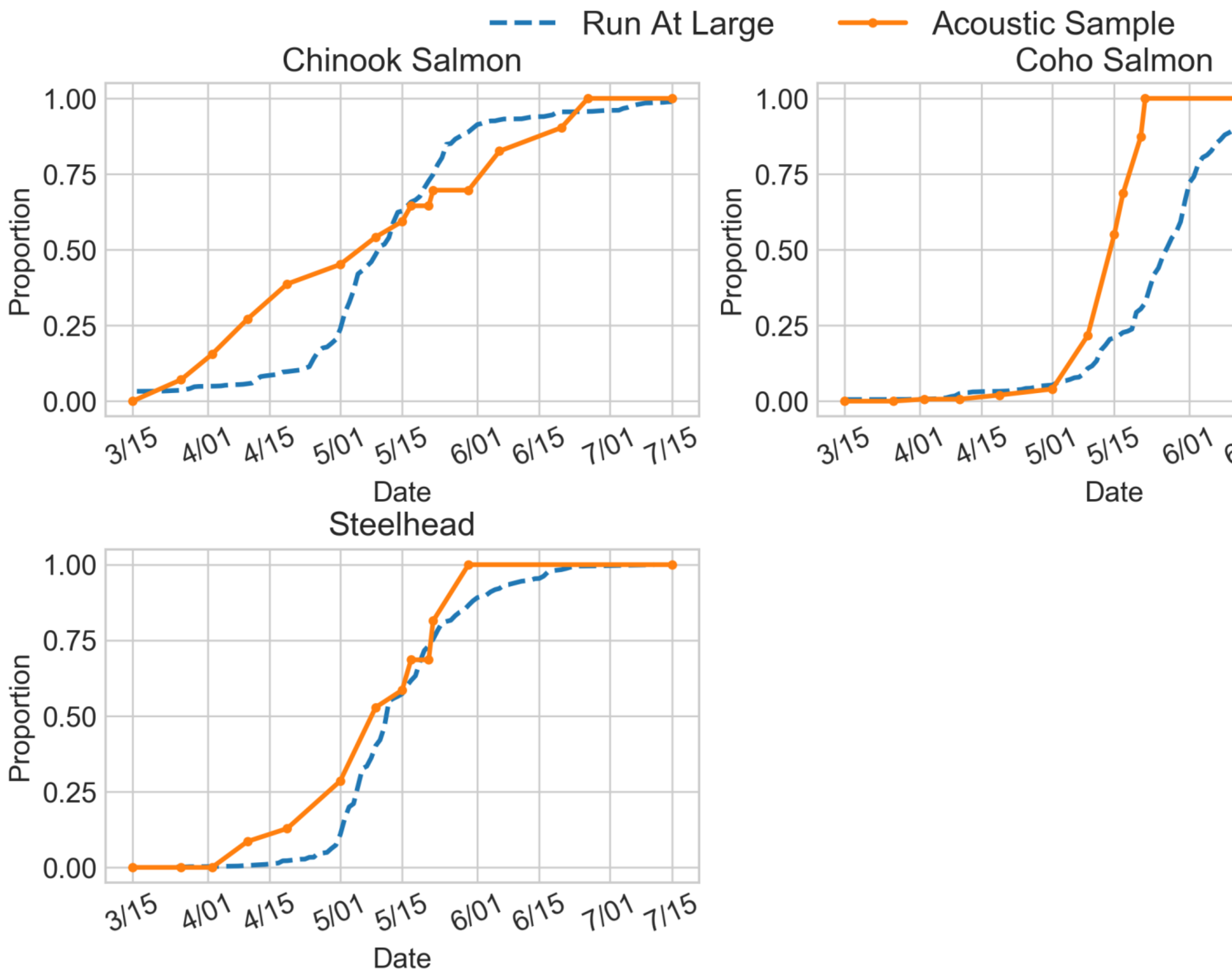
Figure 5. Schematic of zones within the floating surface collector

3 Results

3.1 Telemetry

3.1.1 Tagging and Release

A total of 525 fish were dual-tagged with PIT and acoustic tags and released between March 26 and June 26, 2019, including 155 Chinook Salmon (mean length of 160 mm, range from 90 to 246 mm), 300 Coho Salmon (mean length 182 mm, range from 109 to 258 mm) and 70 steelhead (mean length 219 mm, range from 162 to 322 mm) (Figure 6;

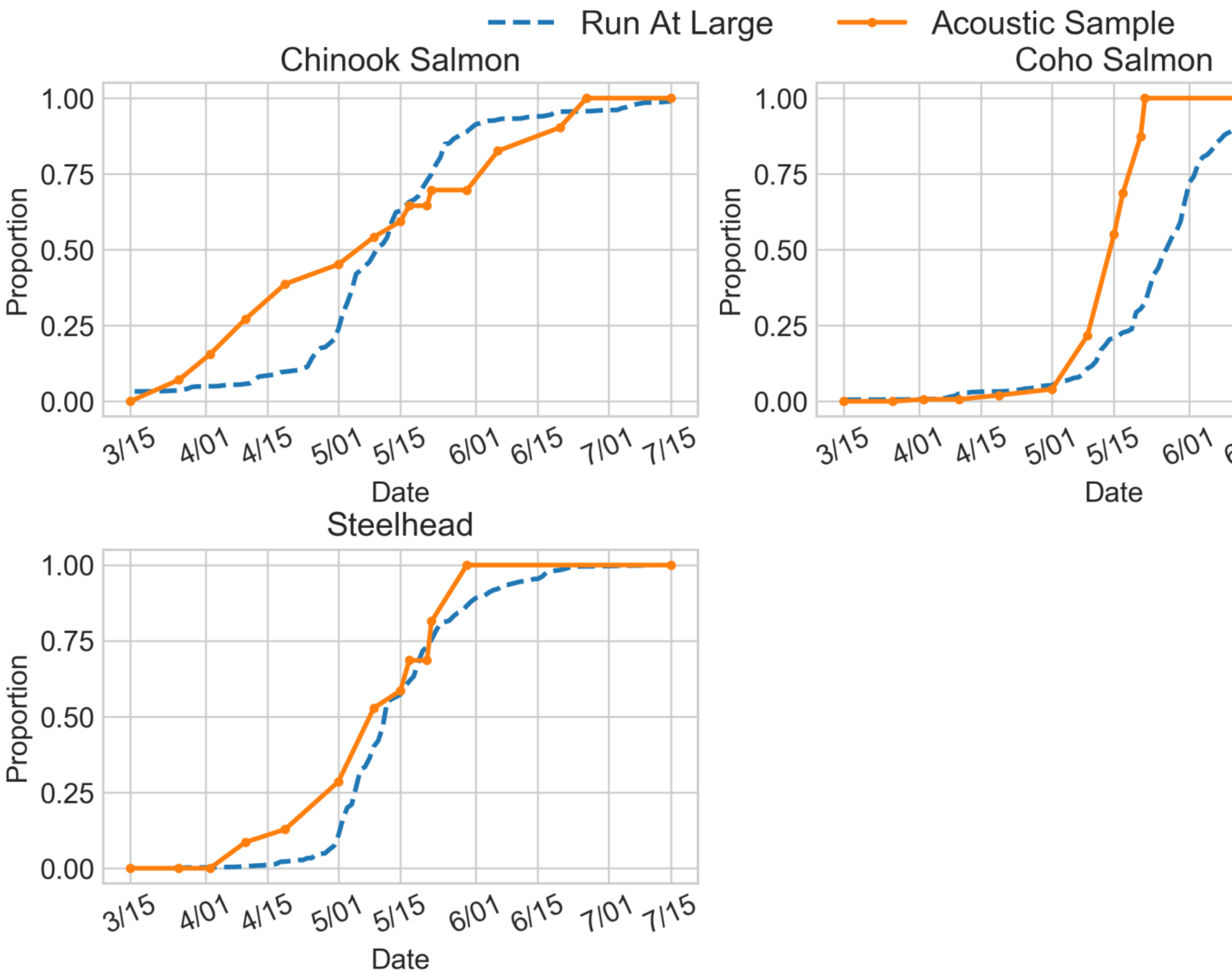


Notes: Blue and orange lines illustrate the number of released individuals in the run at large and the acoustic sample, respectively.

Figure 6. Cumulative distribution functions for number of released individuals for each species

Table 3). Comparison of the daily releases by species with overall collection at the FSC (Figure 6) shows that Chinook Salmon and steelhead releases were proportioned similarly to the runs at large while Coho Salmon releases were weighted more heavily to the earlier stages of the run.

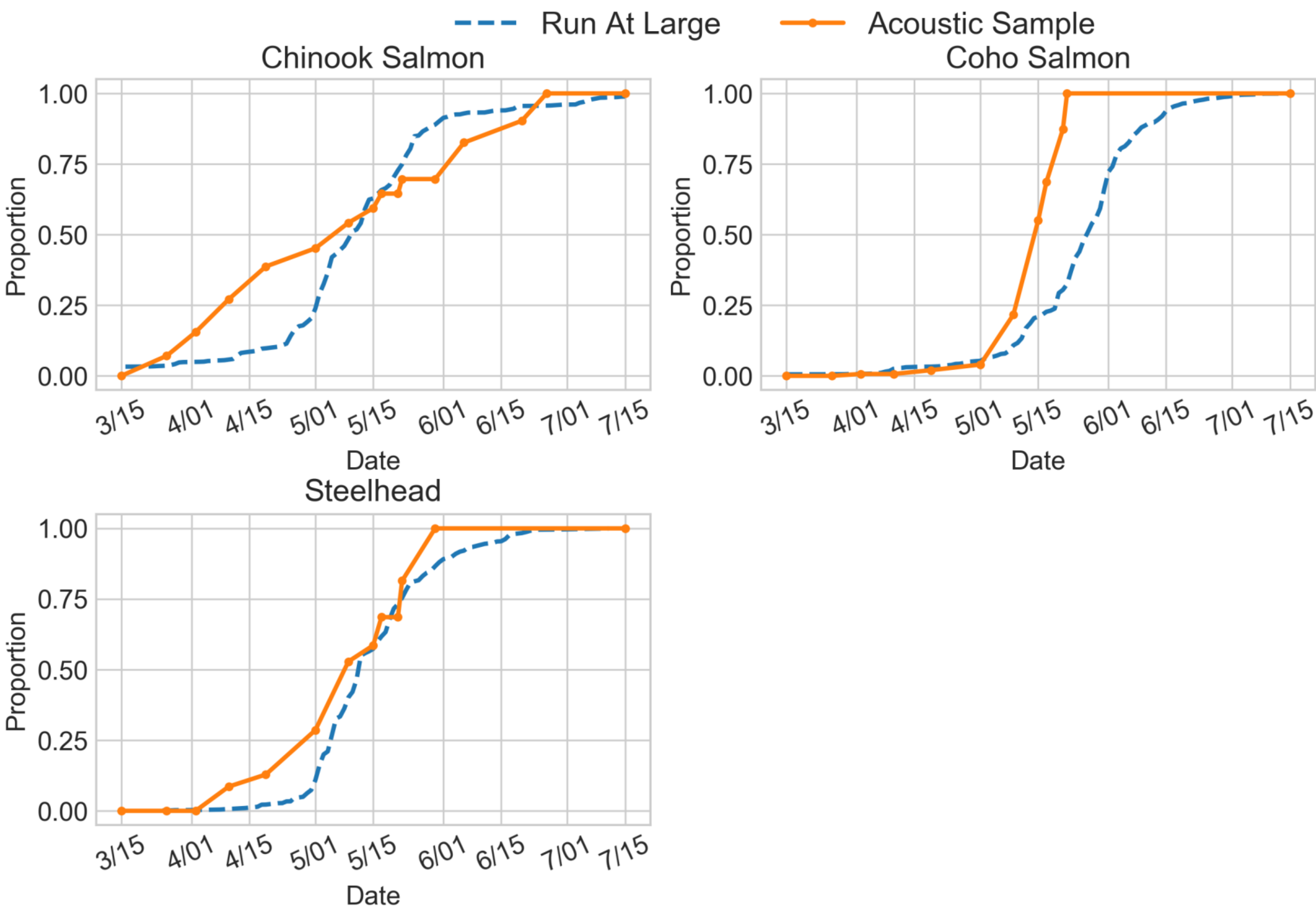
Based on the number of fish recovered with inactive acoustic tags, it is assumed that an unknown number of acoustic tags failed to activate prior to release (



Notes: Blue and orange lines illustrate the number of released individuals in the run at large and the acoustic sample, respectively.

Figure 6. Cumulative distribution functions for number of released individuals for each species

Table 3). The observed rate of inactive tags at recapture was used to estimate the total proportion of inactive tags, as well as the 95% confidence interval (CI) around each proportion for each species. An estimated 26% (CI: 20%, 32%) of all study fish were released with inactive tags (Chinook Salmon: 9.5%, [CI: 2.6%, 18%]; Coho Salmon, 32% [CI: 25%, 39%]; steelhead: 9.1% [CI: 1.4%, 26.1%]). The remaining active tags were sufficient to provide a meaningful comparison to previous studies.



Notes: Blue and orange lines illustrate the number of released individuals in the run at large and the acoustic sample, respectively.

Figure 6. Cumulative distribution functions for number of released individuals for each species

Table 3. Summary of the number and length of salmonids tagged with dual passive integrated transponder and acoustic tags during the 2019 Study

Release Date	Chinook Salmon				Coho Salmon				Steelhead			
	Number Tagged	Known Inactive Tags[1]	Average Length (mm)	Length Range (mm)	Number Tagged	Known Inactive Tags[1]	Average Length (mm)	Length Range (mm)	Number Tagged	Known Inactive Tags[1]	Average Length (mm)	Length Range (mm)
3/26/2019	11	-	166	(111, 228)	-	-	-	-	-	-	-	-
4/2/2019	13	-	197	(144, 246)	2	-	114	(109, 119)	-	-	-	-
4/10/2019	18	-	220	(197, 235)	-	-	-	-	6	-	307	(285, 322)
4/19/2019	18	-	208	(161, 242)	4	-	166	(137, 180)	3	-	267	(262, 270)
5/1/2019	10	-	175	(148, 198)	6	-	174	(156, 195)	11	-	197	(162, 237)
5/9/2019	14	1	164	(135, 202)	53	3	196	(135, 231)	17	-	212	(163, 258)
5/15/2019	8	-	169	(143, 190)	100	9	185	(138, 251)	4	-	204	(177, 217)
5/17/2019	8	-	182	(135, 216)	41	13	188	(156, 232)	7	-	202	(149, 272)
5/21/2019	0	-	-	-	56	18	175	(127, 258)		-	-	-
5/22/2019	8	-	157	(139, 175)	38	7	172	(137, 208)	9	1	188	(168, 206)
5/30/2019	0	-	-		-	-	-	-	13	-	221	(170, 296)
6/6/2019	20	3	98	(90, 107)	-	-	-	-	-	-	-	-
6/20/2019	12	-	104	(94, 120)	-	-	-	-	-	-	-	-
6/26/2019	15	-	106	(96, 116)	-	-	-	-	-	-	-	-
Total	**155**	**4**	**160**	**(90, 246)**	**300**	**50**	**182**	**(109, 258)**	**70**	**1**	**219**	**(162, 322)**

Note:
1. The Known Inactive Tags column shows the number of fish collected with inactive acoustic tags.

3.1.2 Detection Efficiency

The detection arrays at Devil's Backbone and ZOI had 100% detection efficiency. The NTS array was found to have slightly less than 100% detection efficiency (Table 4). This is because the few fish missed on the NTS array appear to have traveled quickly through the array, and thus, avoided detection. Detection efficiency estimates were used to correct performance metric estimates to account for fish that may have been present at the array but remained undetected.

Table 4. Autonomous array detection efficiency summary

Species	Detection Efficiency of Swift Forebay Array (%)	Fish Missed at Swift Forebay Array	ZOI Array Detection Efficiency (%)	Fish Missed at the ZOI	Entrance Array Detection Efficiency (%)	Fish Missed at Entrance Array
Chinook Salmon	100	0	100	0	97 (84, 100)	1
Coho Salmon	100	0	100	0	98 (93, 100)	2
Steelhead	100	0	100	0	100	0
All (Weighted Average)	100	0	100	0	98 (94, 99)	3

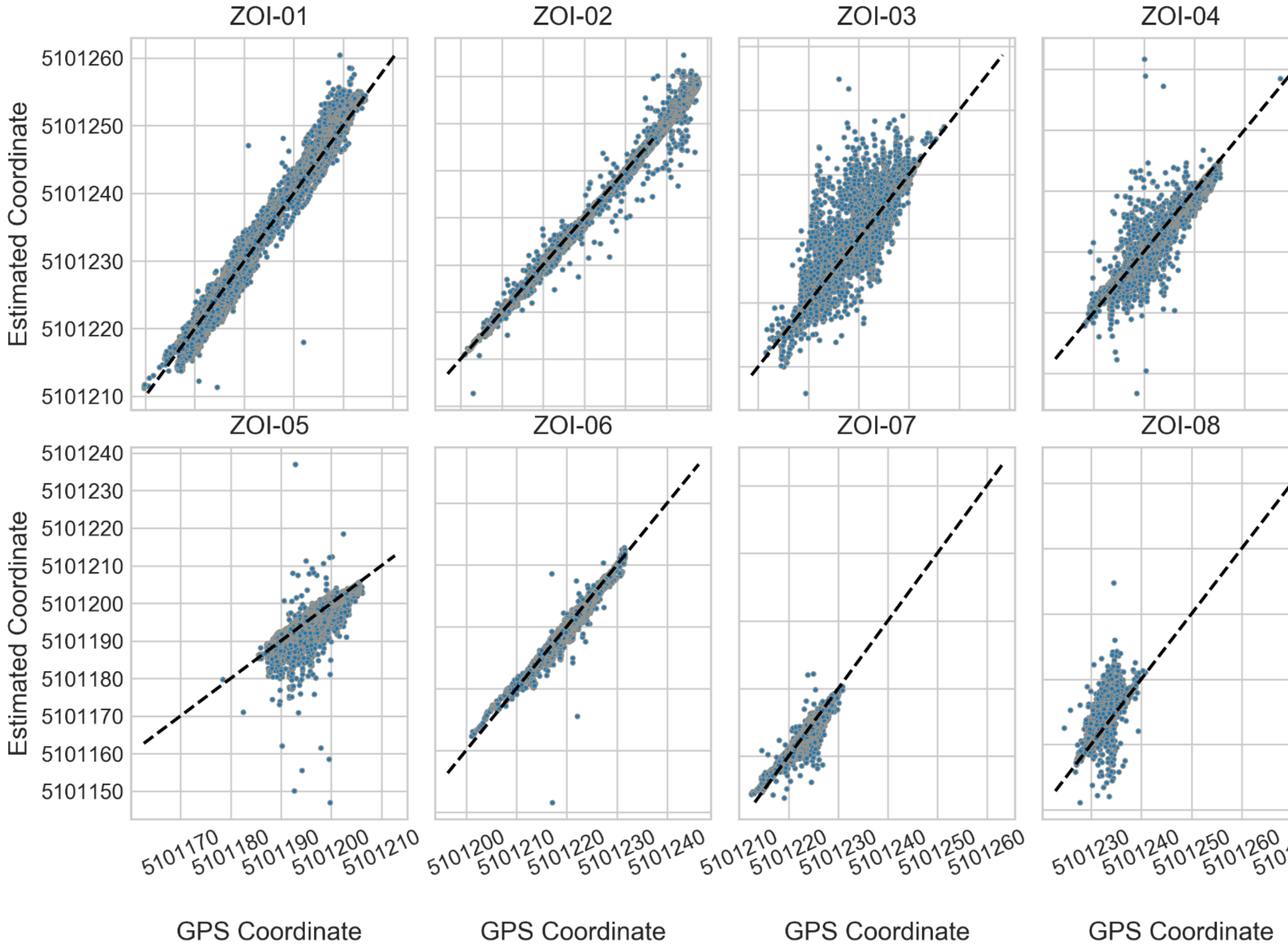
3.1.3 Acoustic Receiver Range Estimation

Range testing showed full coverage of the area within the ZOI array using 2D data. Final fish position data confirmed complete coverage within the anticipated position solution domain, which includes approach pathways from the direction of Devil's Backbone to the ZOI.

Beacon tags deployed on the presence-absence receivers at the Swift forebay array provided confirmation that the receivers in the Swift forebay array (Figure 3) provided sufficient detection range throughout the season and likely detected all fish entering the Swift forebay through the 875-foot span between the tip of the Devil's Backbone to the southern shoreline. This assumption is supported by the 100% detection efficiency observed at the Swift forebay array.

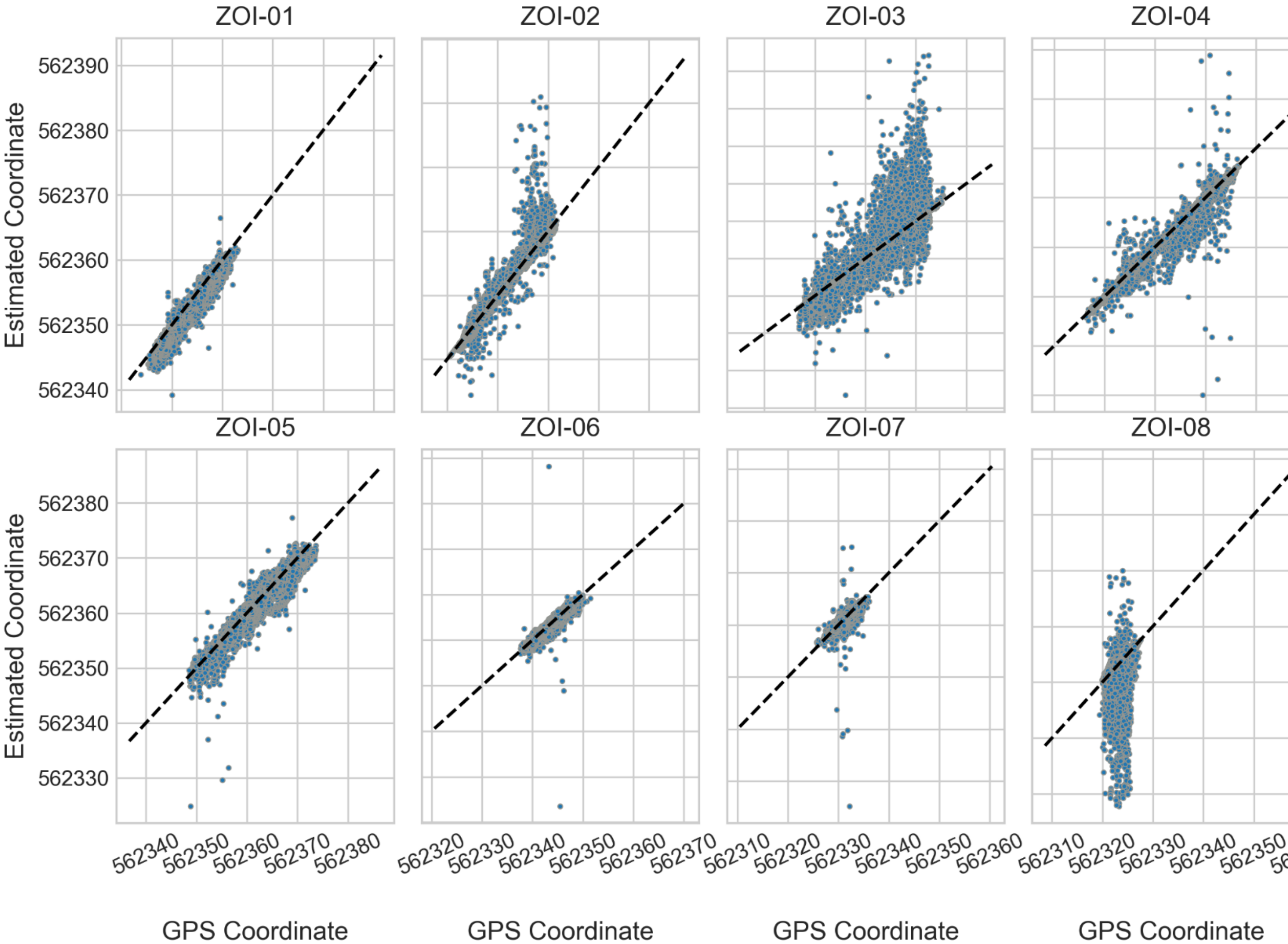
3.1.4 2D Position Estimates

Position estimate accuracy was evaluated and determined to be acceptable for the study by comparing the position estimates of each beacon tag with the position recorded by the GPS installed on the receiver to which the beacon was attached. This included receivers ZOI-01 through ZOI-08. The NTS-09 and NTS-10 were not included because they did not have beacons attached. Beacon tag position estimates were paired with the GPS measurement in closest temporal proximity. Paired northing (i.e., Y) and easting (i.e., X) coordinates were compared separately to estimate the magnitude of differences between the receiver coordinate as estimated by the 2D position estimate of the beacon and the receiver coordinate as estimated by the GPS installed on the receiver.



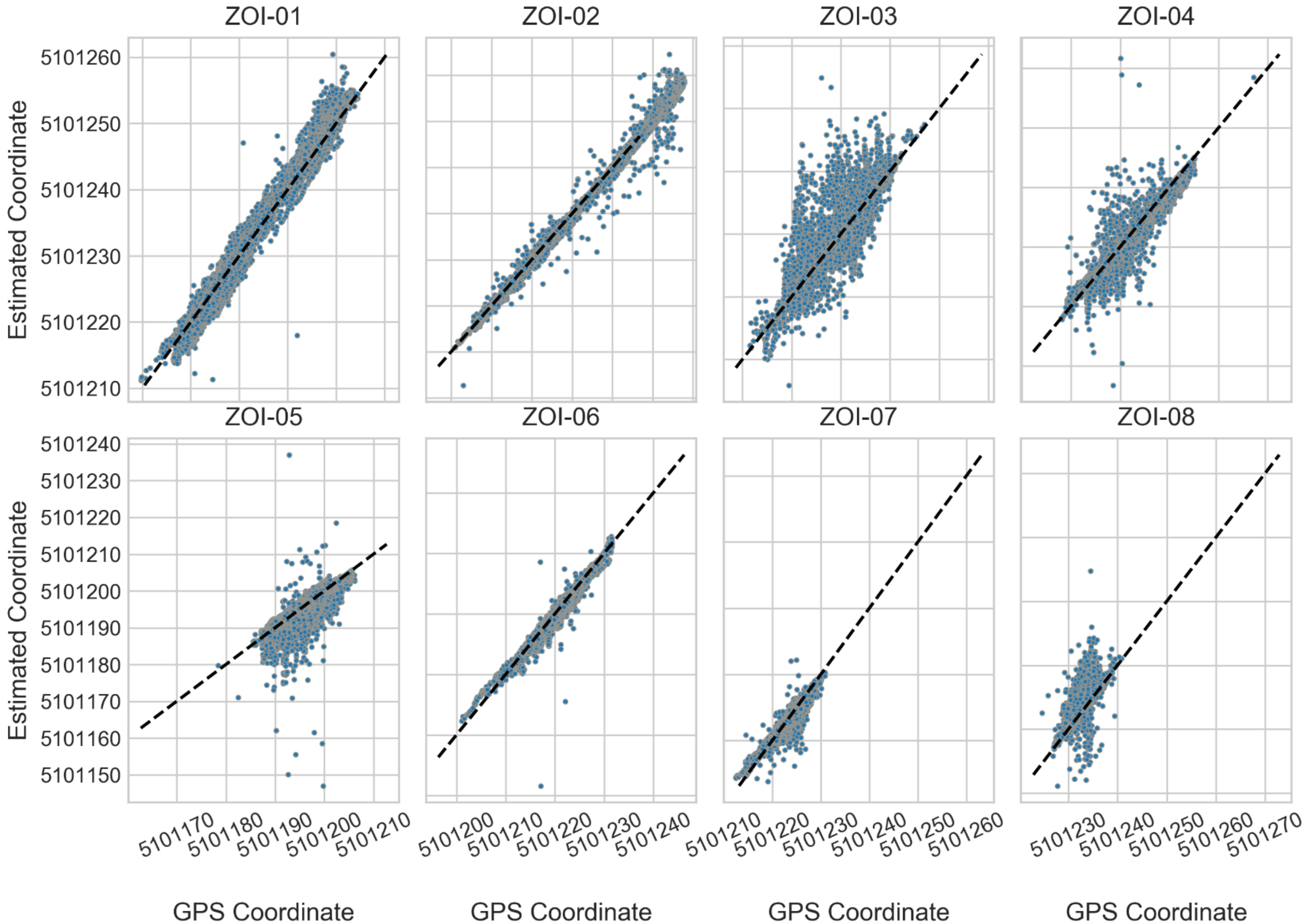
Notes: Coordinate values are given in meters within the Universal Trans Mercator coordinate system. Gray lines illustrate 10 m by 10 m grid cells, and the black dashed line shows the 1-to-1 line.

Figure 7 and



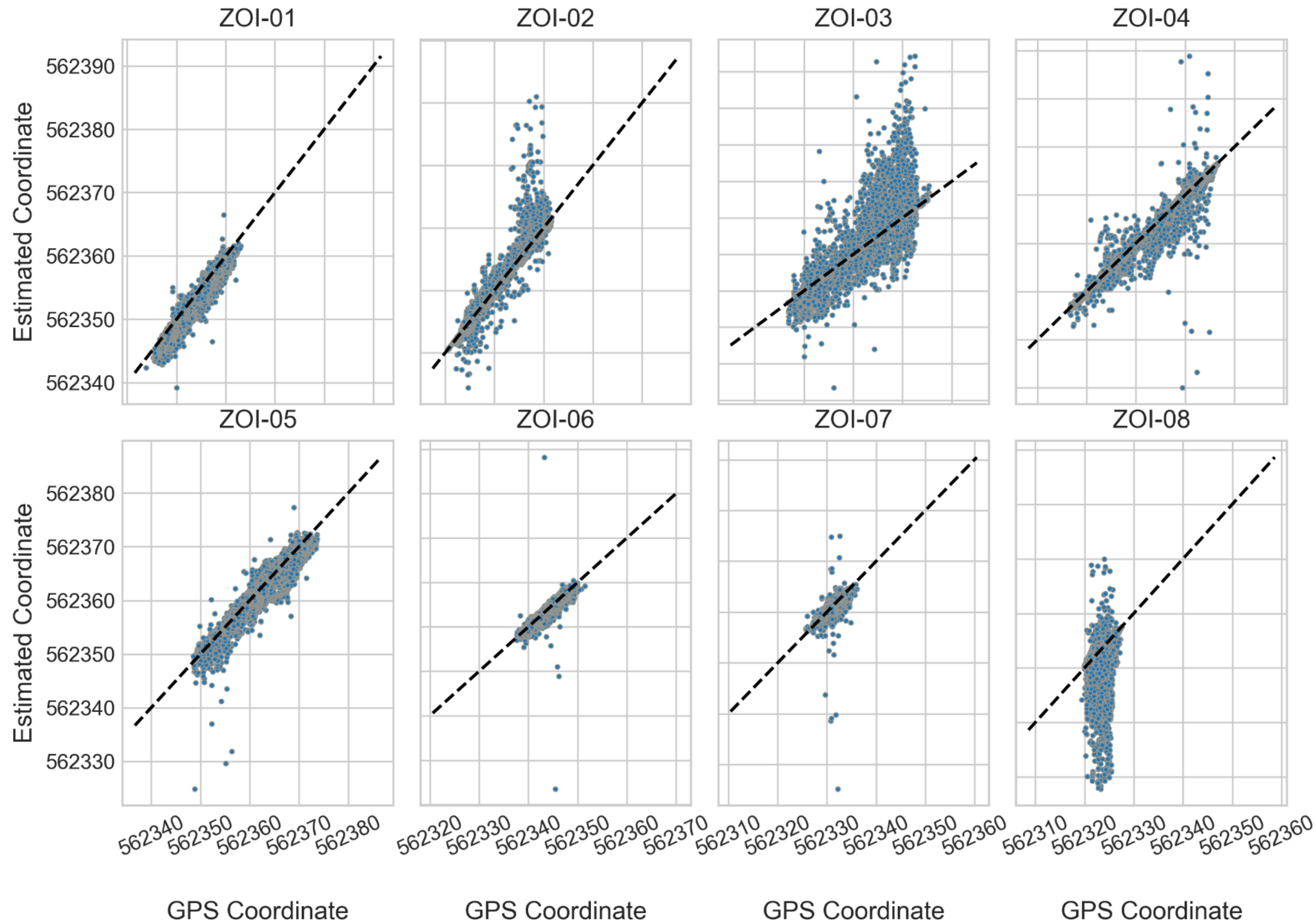
Notes: Coordinate values are given in meters within the Universal Trans Mercator coordinate system. Gray lines illustrate 10 m by 10 m grid cells, and the black dashed line shows the 1-to-1 line.

Figure 8 show an example of these comparisons for a subset of the data collected between June 6 and June 21. Plots comparing the time series of position estimates were also reviewed.



Notes: Coordinate values are given in meters within the Universal Trans Mercator coordinate system. Gray lines illustrate 10 m by 10 m grid cells, and the black dashed line shows the 1-to-1 line.

Figure 7. Scatterplots illustrating the relationship between GPS and estimated Northing coordinate values for beacon tags on all zone of influence receivers positioned during the June 6 to June 21 period



Notes: Coordinate values are given in meters within the Universal Trans Mercator coordinate system. Gray lines illustrate 10 m by 10 m grid cells, and the black dashed line shows the 1-to-1 line.

Figure 8. Scatterplots illustrating the relationship between GPS and estimated Easting coordinate values for beacon tags on all zone of influence receivers positioned during the June 6 to June 21 period

Position accuracy is greatest on receivers in the center of the array (ZOI-01, ZOI-05, ZOI-06, and ZOI-07) due in part to signals from beacons (and fish) in this part of the array having the greatest probability of being received on multiple receivers, which improves position estimate accuracy. Position accuracy decreases towards the boundaries of the array as signals from these locations may not be received on as many receivers. The level of overall accuracy of the position solution is sufficient for this study as it has the highest accuracy in the approach vectors leading up to the collector along the southern side of the lead net. The full set of figures documenting position accuracy throughout the study period are provided in Appendix A.

3.2 Performance Metrics

The 2019 performance metrics are summarized in Table 5 and Figure 9. Overall, Coho Salmon had the highest (64%) and steelhead had the lowest (27%) P_{CE}. All three species combined had the highest P_{CE} of any comparable study year to date (Table 1; Appendix B). It should be noted that the derived value P_{CE} for steelhead in 2018 was likely higher although the study methodology was not directly comparable. The other performance metrics corrected for array detection efficiency that were calculated to evaluate fish behavior through the system include the following:

- Of the 525 fish released at Eagle Cliff near the upper end of Swift Reservoir, 303 were detected entering the Swift Dam forebay; however, because an unknown portion of acoustic tags appear to have not activated (see Section 3.1.1), using these detections in the forebay to estimate P_{RES} would have been biased. Therefore, P_{RES} was estimated using the corrected form of the calculation shown in Table 2 that relies on the unbiased estimates of the remaining metrics to algebraically determine P_{RES}. The corrected P_{RES} metrics are 63% of Chinook Salmon, 86% of Coho Salmon, and 63% of steelhead.
- A total of 279 out of 303 acoustic tagged fish detected entering the Swift Dam forebay were detected in the ZOI (P_{ENC}). Coho Salmon had the greatest number detected in proportion to total number entering the forebay (95%), followed by steelhead and Chinook Salmon (93% and 85%, respectively).
- Of the 279 acoustic tagged fish detected entering the ZOI, 254 were estimated to have entered the NTS (P_{ENT}), including 78% of Chinook Salmon, 98% of Coho Salmon, and 97% of steelhead.
- Of the 254 fish that were estimated to have entered the NTS, 154 were collected (P_{RET}). Of the fish entering the NTS, 65% of Chinook Salmon, 65% of Coho Salmon, and 28% of steelhead were collected. There was a total of 209 study fish collected out of the 525 released; however, fish with inactive tags were not used to calculate metrics.

Table 5. 2019 Performance metric summary

Species	Released	Detected at Swift Forebay	Detected at ZOI	Detected at Entrance Array	Collected[1]	$\hat{P}_{RES}$ % (CI)	$\hat{P}_{ENC}$ % (CI)	$\hat{P}_{ENT}$ % (CI)	$\hat{P}_{RET}$% (CI)	$\hat{P}_{CE}$% (CI)
Chinook Salmon	155	88	75	57	42	63% (55.2, 70.4)	85% (76%, 91%)	78% (67%, 86%)	65% (53 77%)	51% (39%, 62%)
Coho Salmon	300	175	167	161	156	86% (81.9, 89.8)	95% (91%, 98%)	98% (93%, 100%)	65% (57%, 72%)	64% (53%, 74%)
Steelhead	70	40	37	36	11	63% (51.5, 74.2)	93% (79%, 84%)	97% (83%, 100%)	28% (13%, 42%)	27% (17%, 37%)
All	525	303	279	254	209	78% (74.8, 81.9)	92% (89%, 95%)	93% (89%, 96%)	60% (53%, 66%)	55% (44%, 67%)

Note:
1. Collected fish include both active and inactive tags. Only fish collected with active tags were used to calculate P_{RET} and P_{CE}.

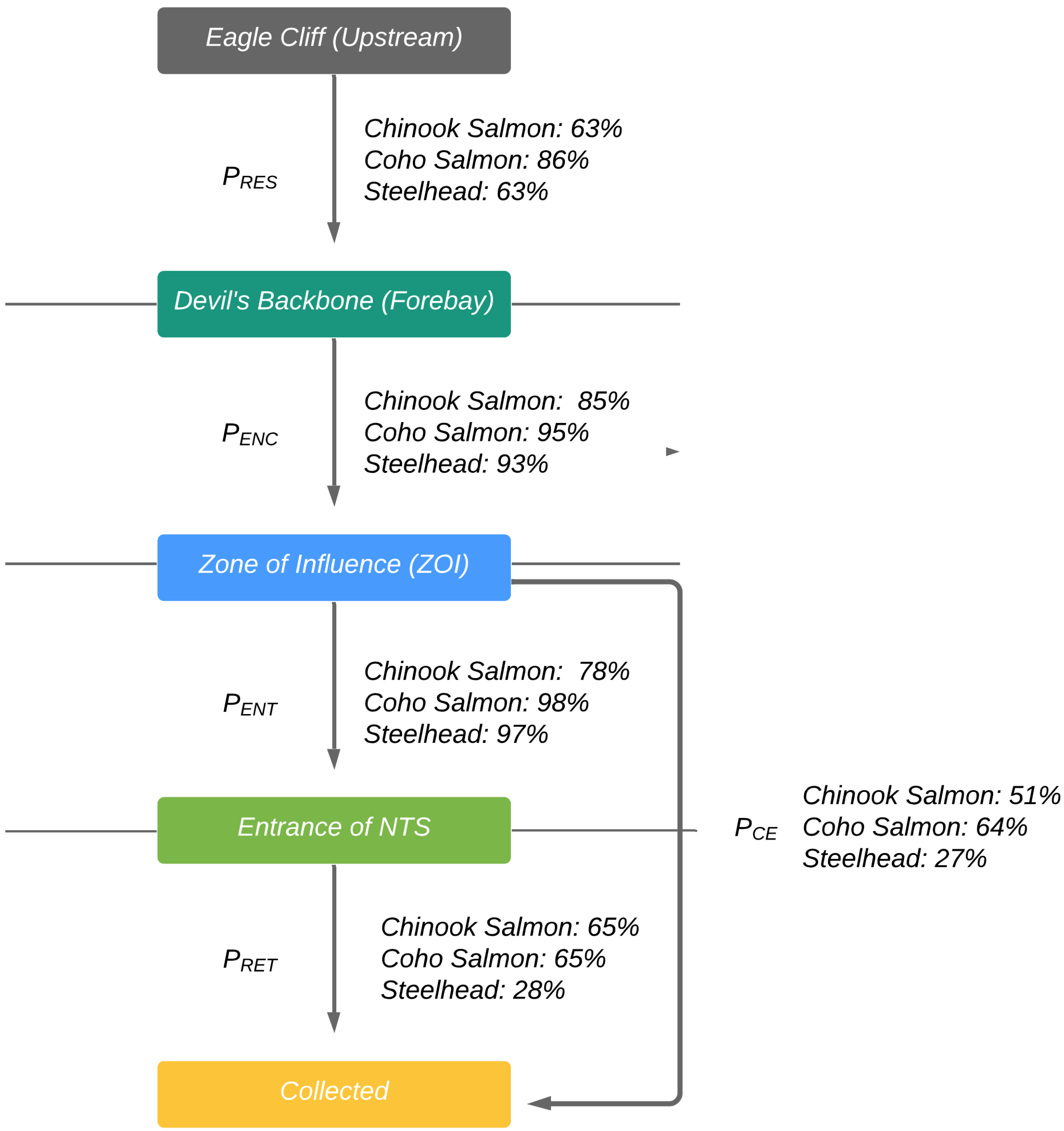


Figure 9. Summary of 2019 performance metrics

3.3 Behavioral Analysis

Fish behaviors described in the following sections were evaluated based on dual PIT- and acoustic-tagged fish.

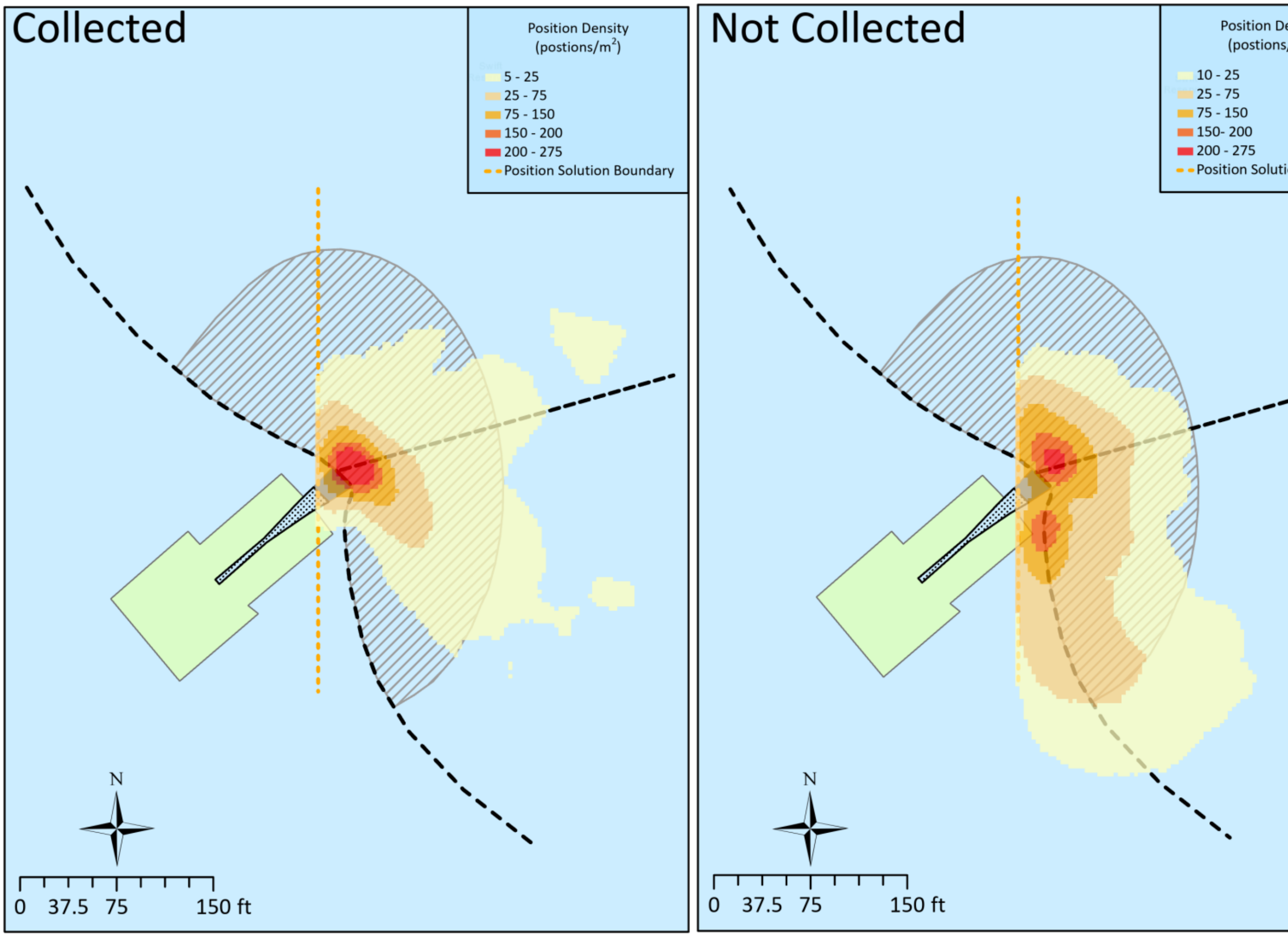
3.3.1 Time of Arrival

Travel time from release to the ZOI was examined for all three species. Median travel time was 6.2 days for Chinook Salmon (range 1.2 to 66.5 days), 3.2 days for Coho Salmon (range 0.6 to 50.2 days), and 3.7 days for steelhead (range 1.4 to 31.3 days). Travel time from release to the ZOI was relatively consistent for steelhead throughout the season, with an interquartile range (IQR, or the difference between the 75th and 25th percentiles) of 3.8 days throughout the season. Conversely, both Coho Salmon (IQR = 5.0 days) and Chinook Salmon (IQR = 12.4 days) had greater variation in travel times, with both species traveling quicker as the season progressed. Median travel times of Coho Salmon and Chinook Salmon released during April were up to 8.5 times slower compared to cohorts released in May. Despite these trends, travel time was unrelated to the probability of collection for all three species (all three $p > 0.38$).

Analysis of collection rates throughout the season and throughout each day revealed species-specific patterns. First, while collection of Chinook Salmon and steelhead were not related to release week, Coho Salmon released in late May were significantly less likely to be collected compared to those released in early May (~18% reduction in collection probability from May 9 to May 21, $p = 0.02$). Surprisingly, the peak collection period (May 22 to June 3) accounted for 60% of recaptured Coho Salmon, though fish released the week of May 21 only accounted for 10 of the 64 fish encountered during that time. Secondly, the time of day when study fish first approached the ZOI was significantly different among species ($p < 0.01$): Chinook Salmon arrived mostly during night (56%), where Coho Salmon and steelhead arrived more frequently during the day (69% and 81%, respectively). Approach timing was unrelated to collection for both Chinook Salmon and Coho Salmon ($p > 0.08$ for both species), though steelhead that arrived in the ZOI during the night were more likely to be collected compared to those that arrived during the day ($p = 0.03$). Lastly, time of day that study fish were collected was significantly different among species ($p < 0.01$): Chinook Salmon were overwhelmingly collected during the night (87%), whereas Coho Salmon and steelhead were collected more frequently during the day (61% and 56% respectively).

3.3.2 *Fish Position*

Position density heat maps of all fish positions by species for collected and not collected fish are displayed in



Notes: The schematic illustrates the ZOI, NTS, FSC, and the lead and barrier nets. Net positions shown (as dashed lines) were delineated from aerial photographs and should be considered as approximate because nets can move with currents and their positions shift daily and seasonally. Additionally, only the approximate position of the top of the net is shown; bowing of the net may cause variation of the position at depth. Fish are not able to move behind the barrier net, and position densities plotted on the collector side of the barrier net lines are likely due to the net position changing throughout the season and/or bowing of the net at depth. Spatial Reference: GCS WGS 1984.

Figure 10,

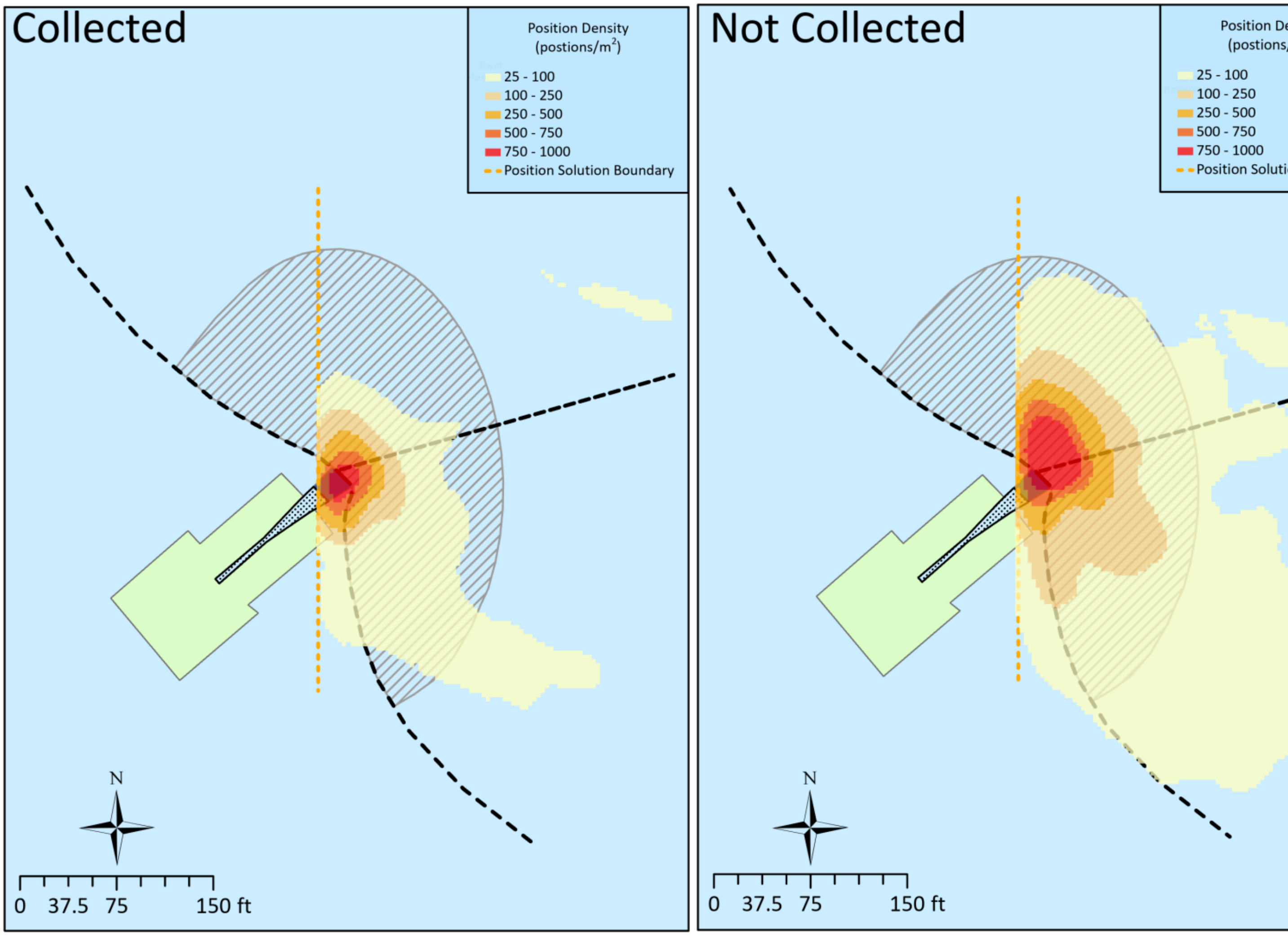


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Figure 11, and

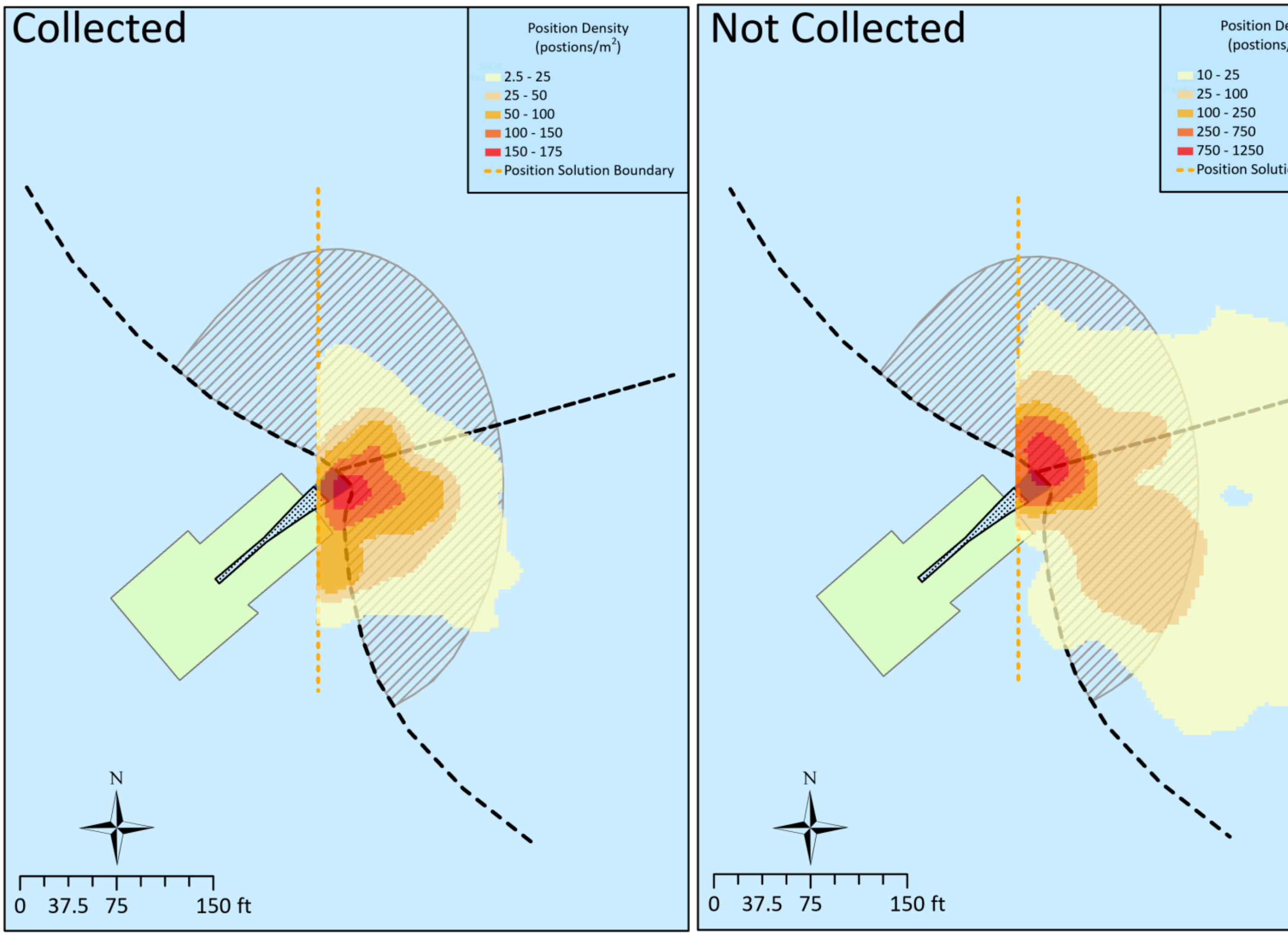

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Figure 12. For all species and both collected vs. not-collected fish, the density of position estimates was highest in front of and inside the NTS. This pattern indicates that all fish, whether collected or not, congregate at and immediately within the entrance of the NTS. Collected fish for all three species were generally less widely distributed throughout the ZOI, while not-collected fish appeared to roam more extensively throughout the ZOI and adjacent forebay areas, although highest densities were still at the entrance of the NTS. Not-collected Chinook Salmon also appeared to congregate along the barrier net immediately to the south of the NTS.

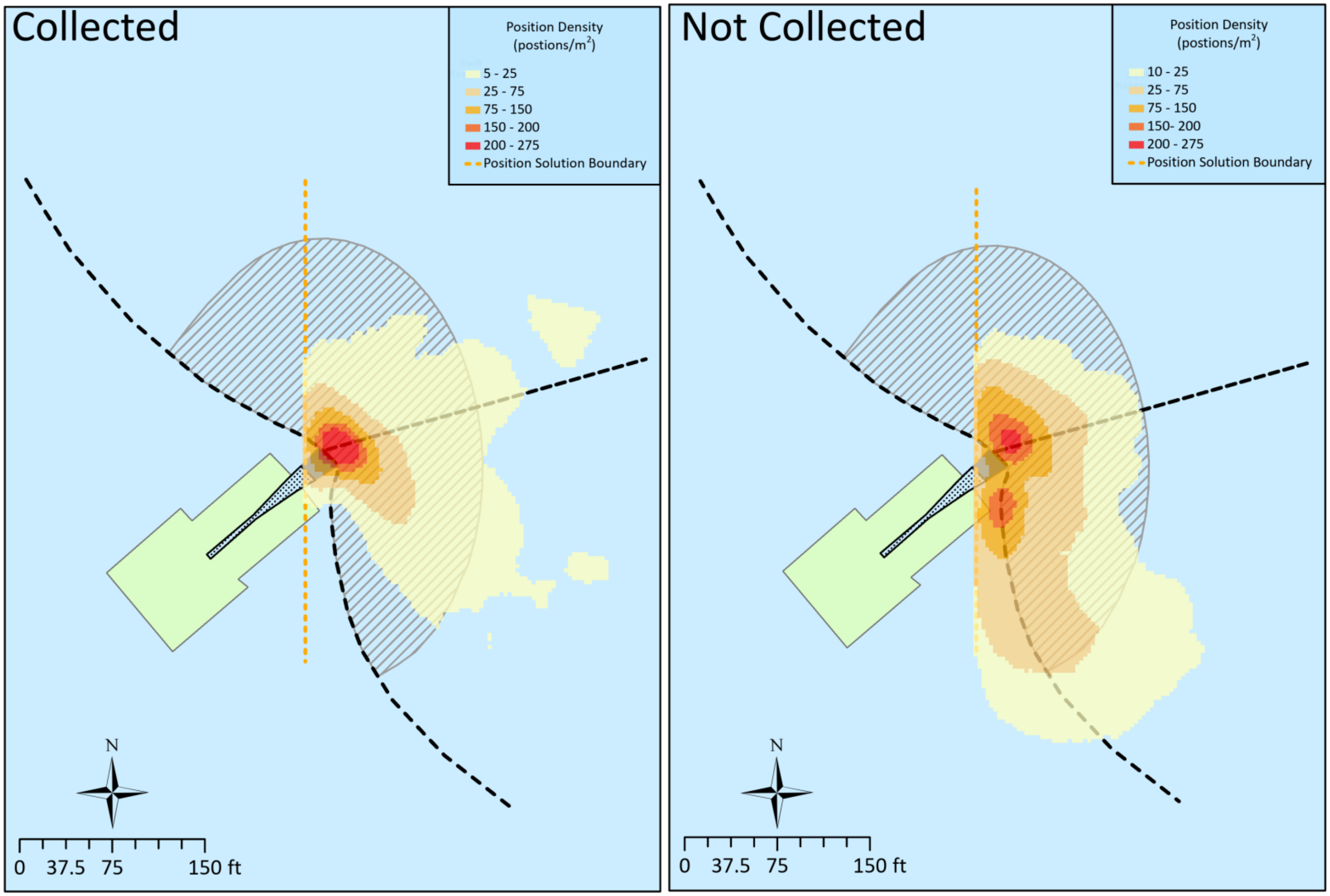

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Figure 10. Heatmap showing density of all positions estimated for Chinook Salmon

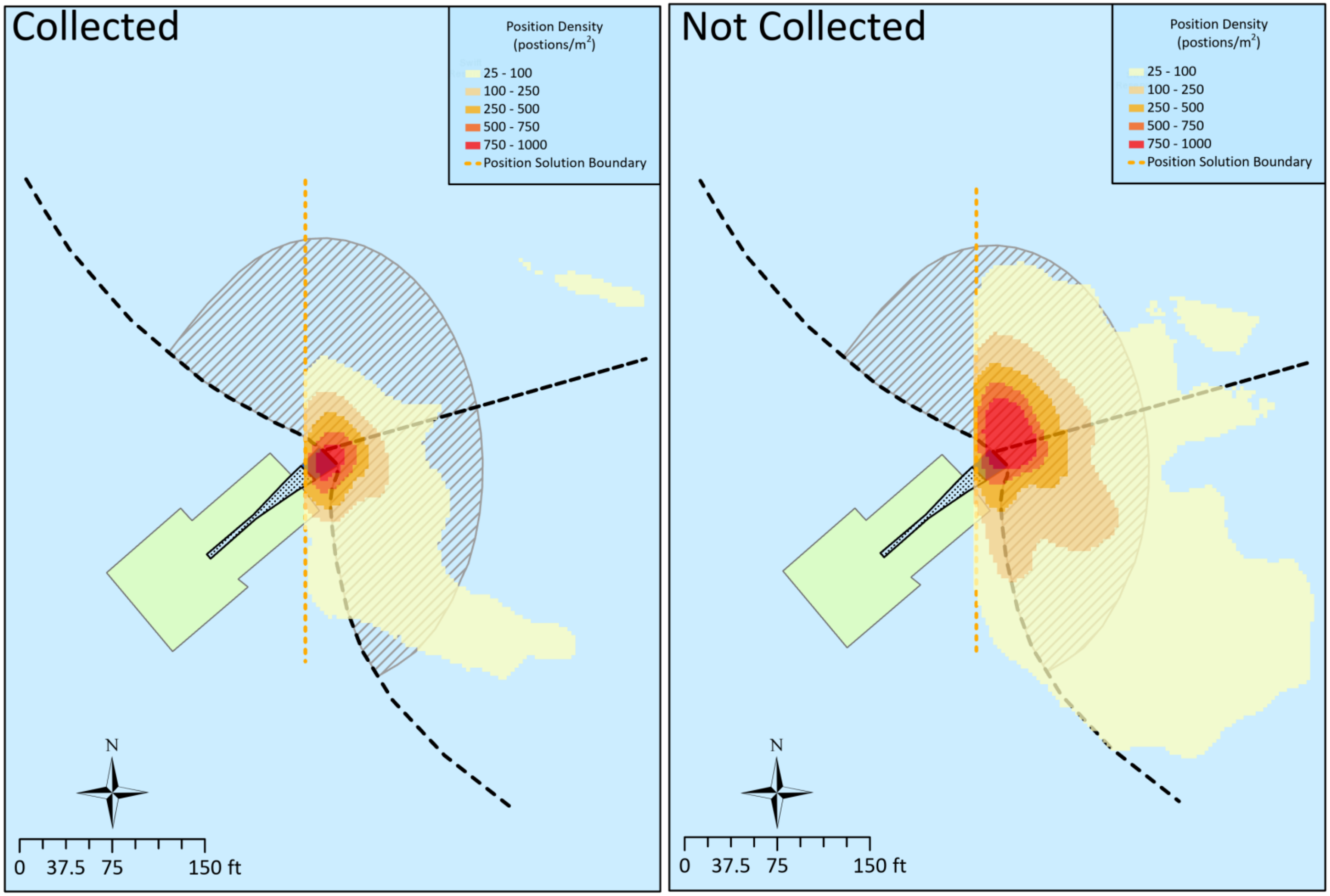

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Figure 11. Heatmap showing density of all positions estimated for Coho Salmon

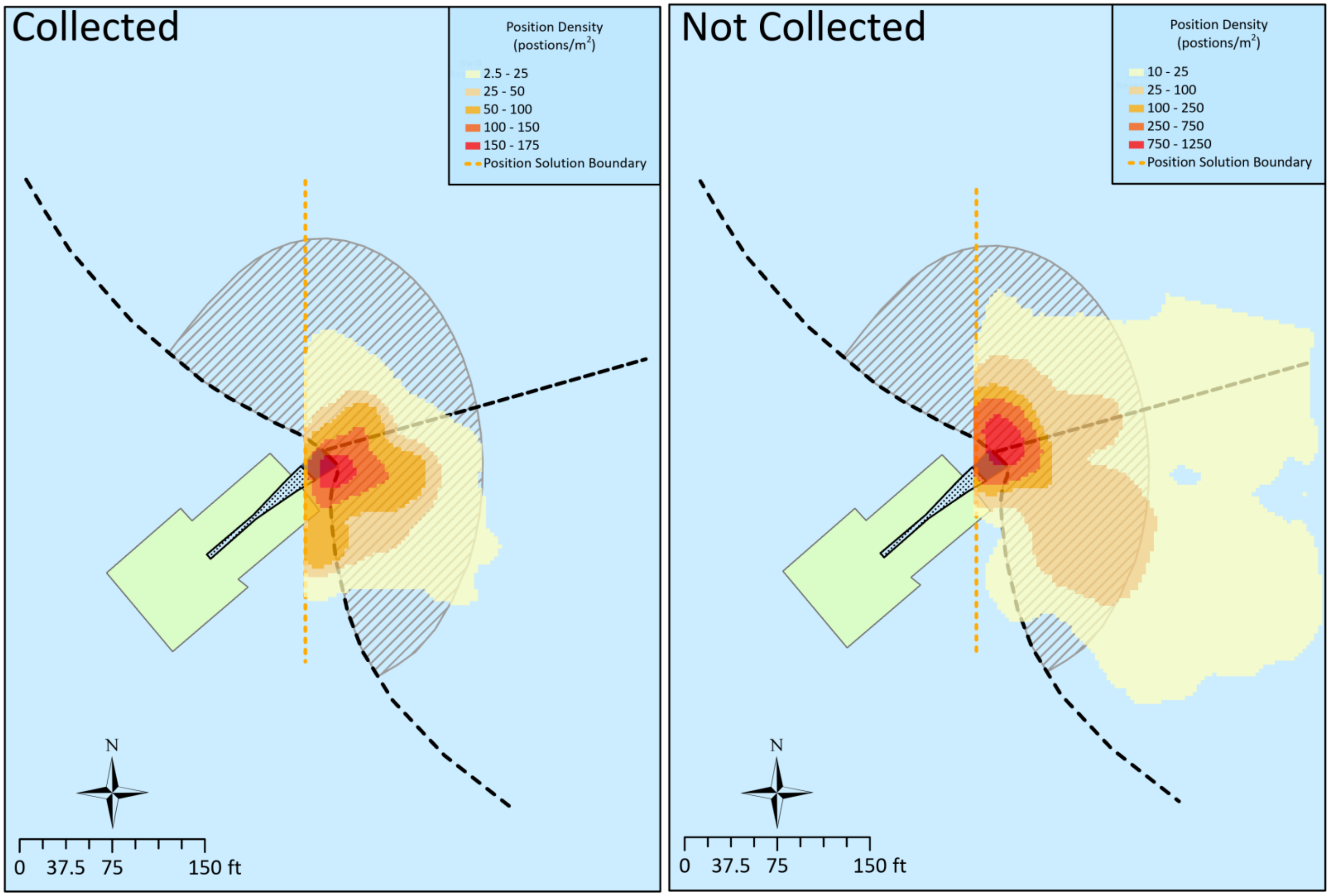

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Figure 12. Heatmap showing density of all positions estimated for steelhead

3.3.3 Arrival and Collector Approach Direction

Position density heat maps using the first 30 minutes of 2D positions within the ZOI by species and collection status (i.e., collected vs. not-collected) are shown in

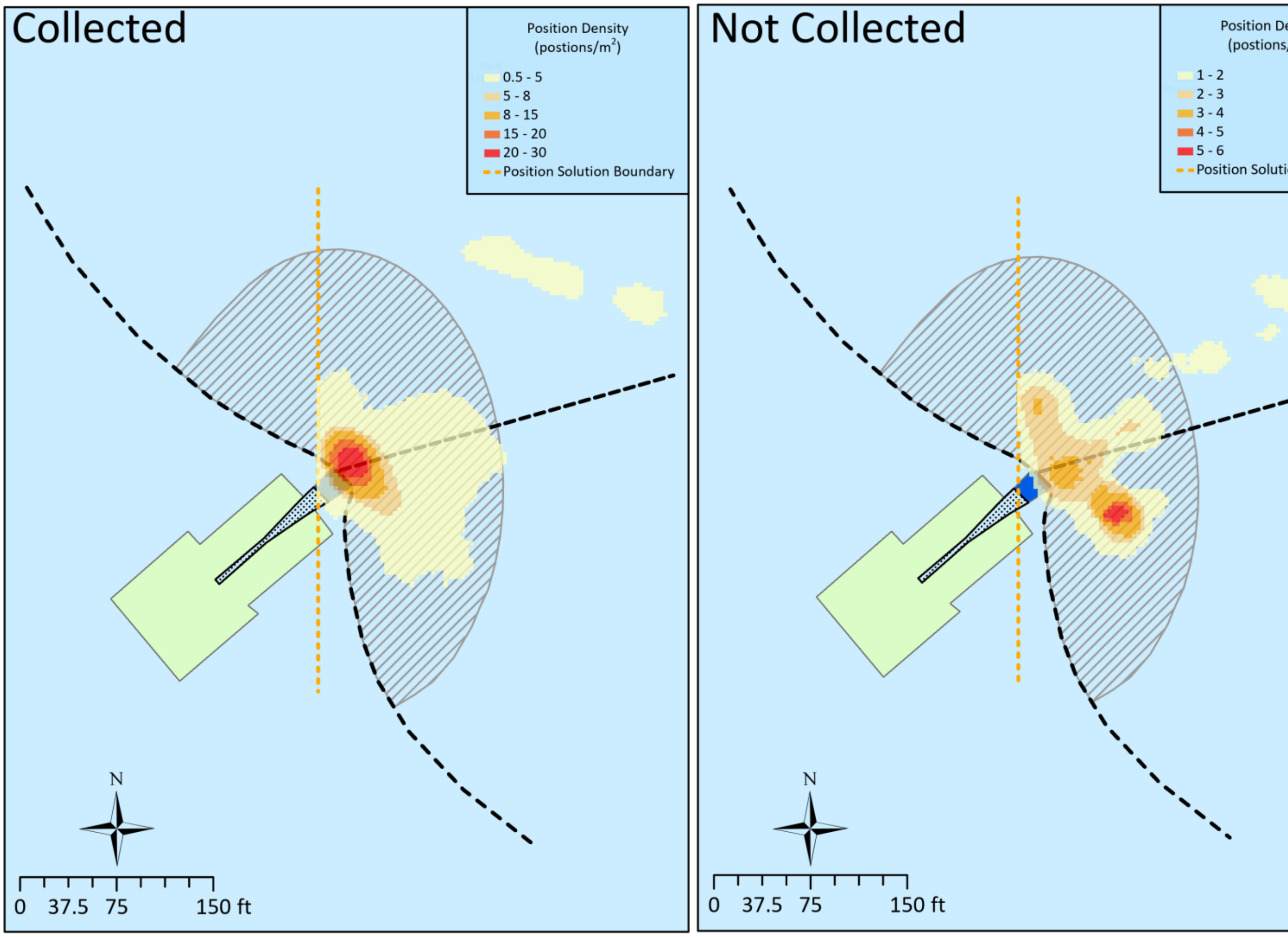

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Figure 13,

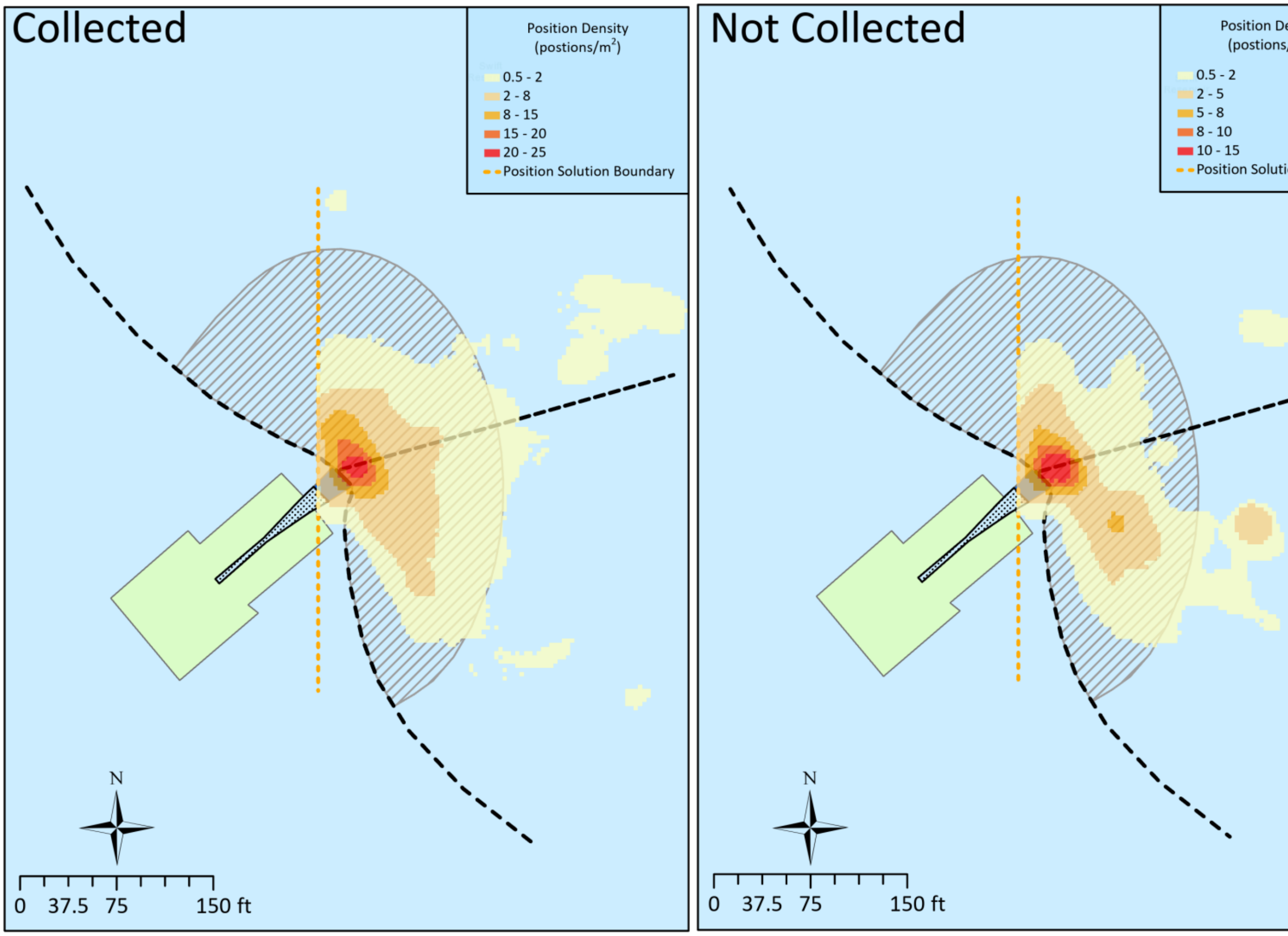

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Figure 14, and

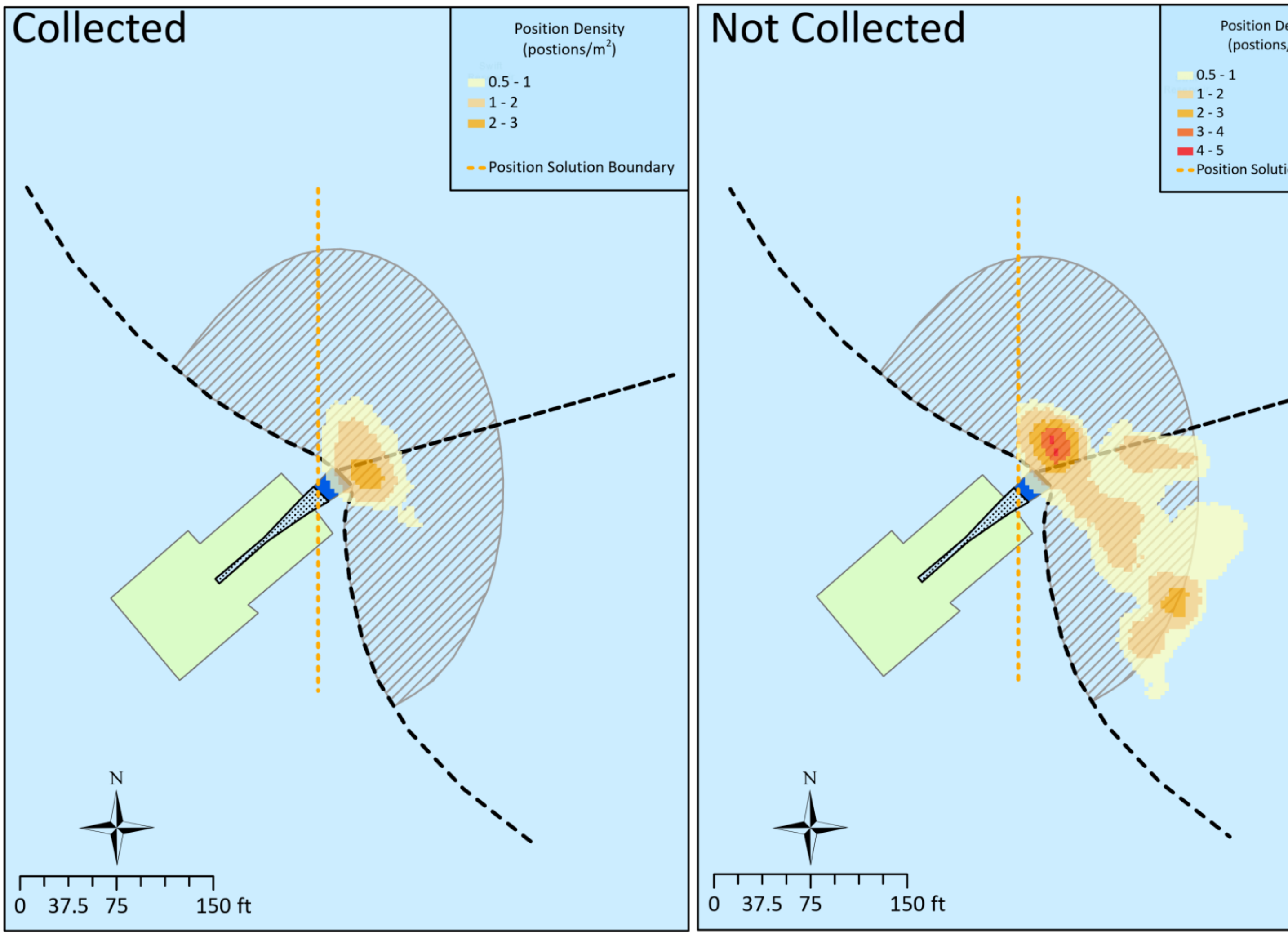

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Figure 15. Collected and not-collected fish of all three species show high position densities at the entrance of the NTS in these initial positions within the ZOI. This suggests that fish are locating and moving towards the entrance of the NTS shortly after first arriving in the ZOI regardless of whether they are ultimately collected. Still, collected fish have the highest density of initial positions at the collector entrance while initial positions in the ZOI for not collected fish are more widely distributed with concentration of positions to the south of the NTS as well as at the NTS entrance for all species.

Position density heat maps using the last 30 minutes that fish were within the ZOI were used to evaluate final approach to the collector for collected fish and ZOI exit routes for fish that were not collected (

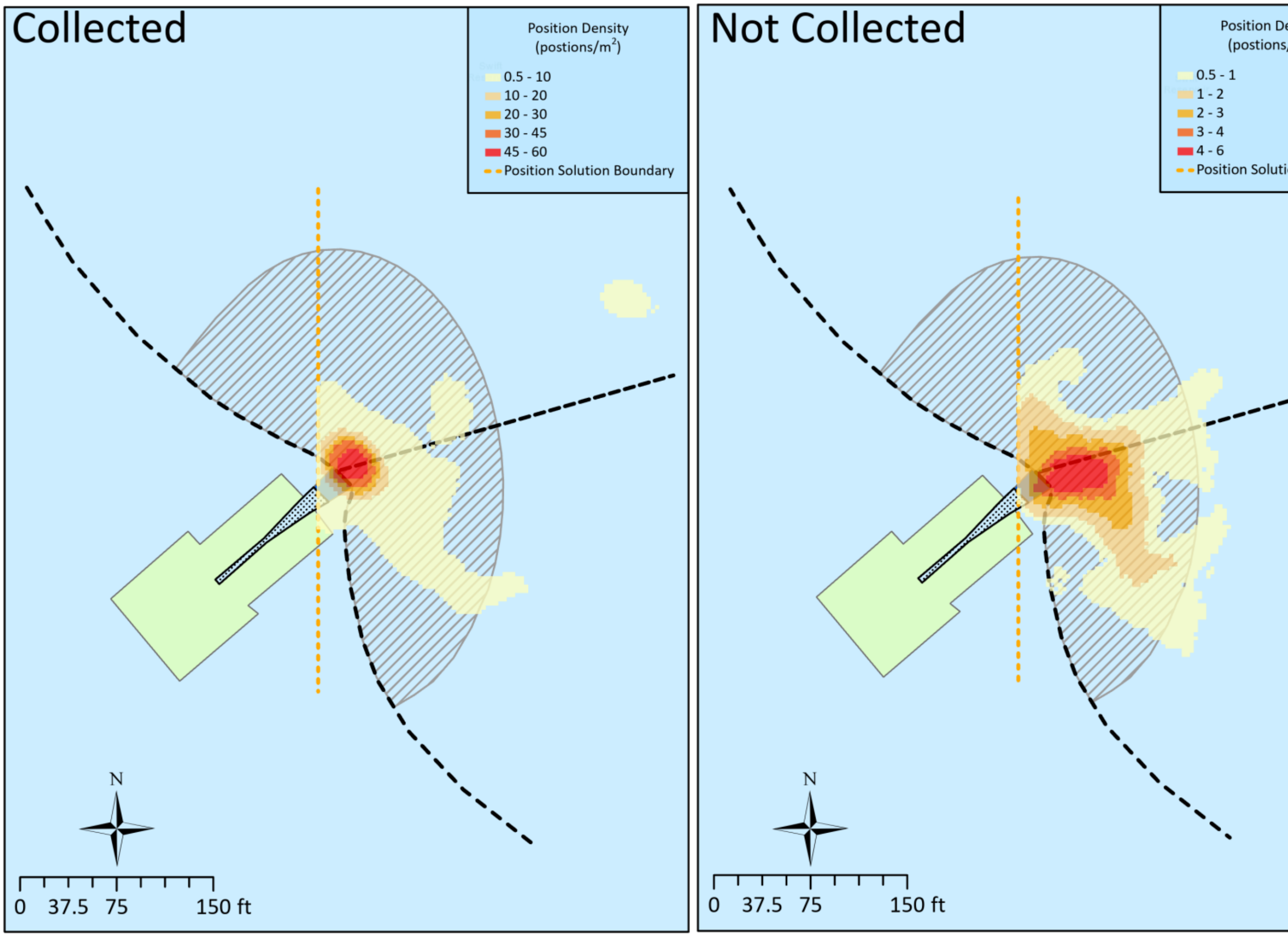

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Figure 16;

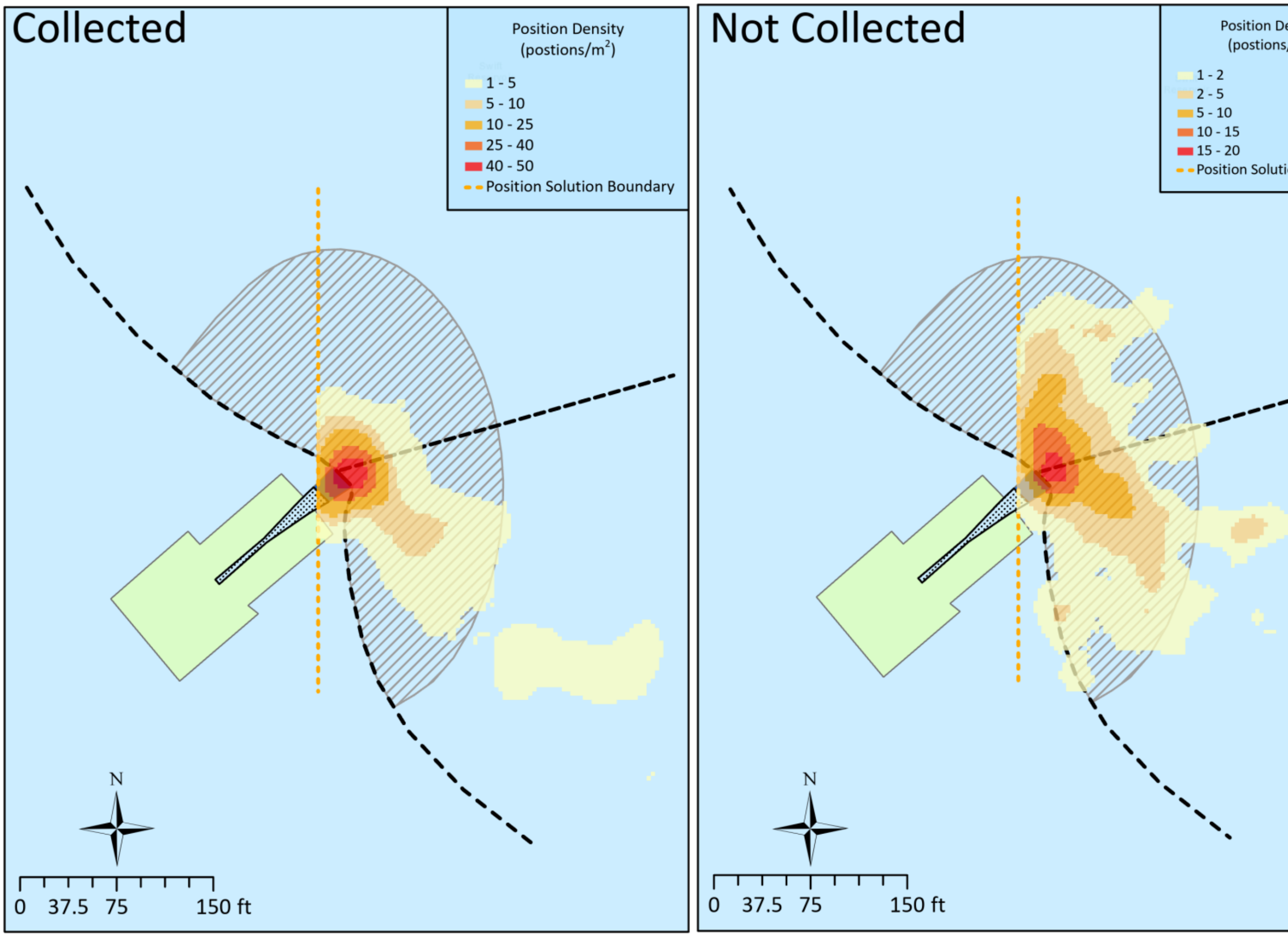

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Figure 17;

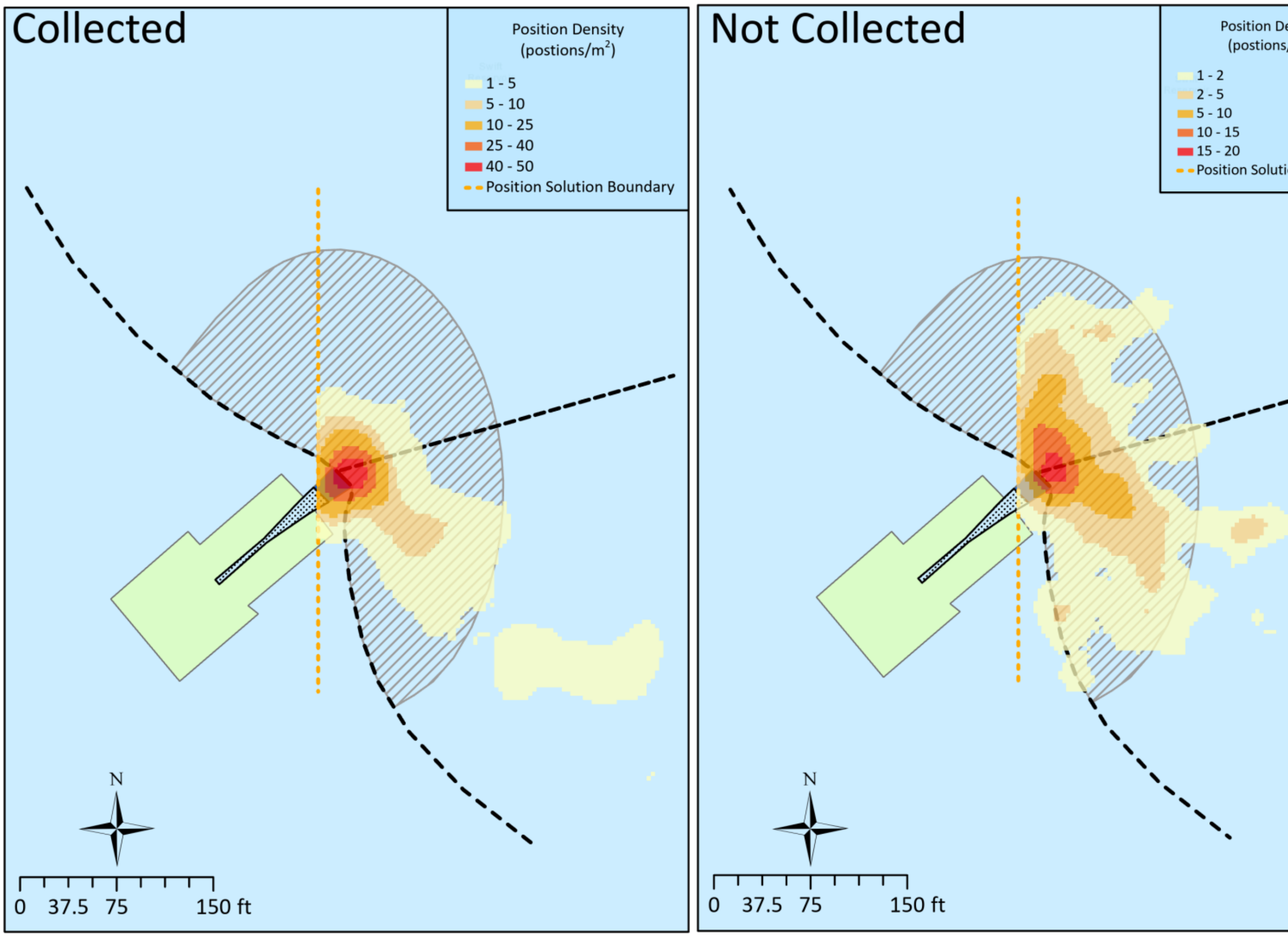

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Figure 18). Regardless of collection status, all three species had the highest density of final positions in front of the collector entrance and within the NTS. This indicates that even fish that are not collected are still congregating at the entrance of the NTS shortly before leaving the ZOI for the final time.

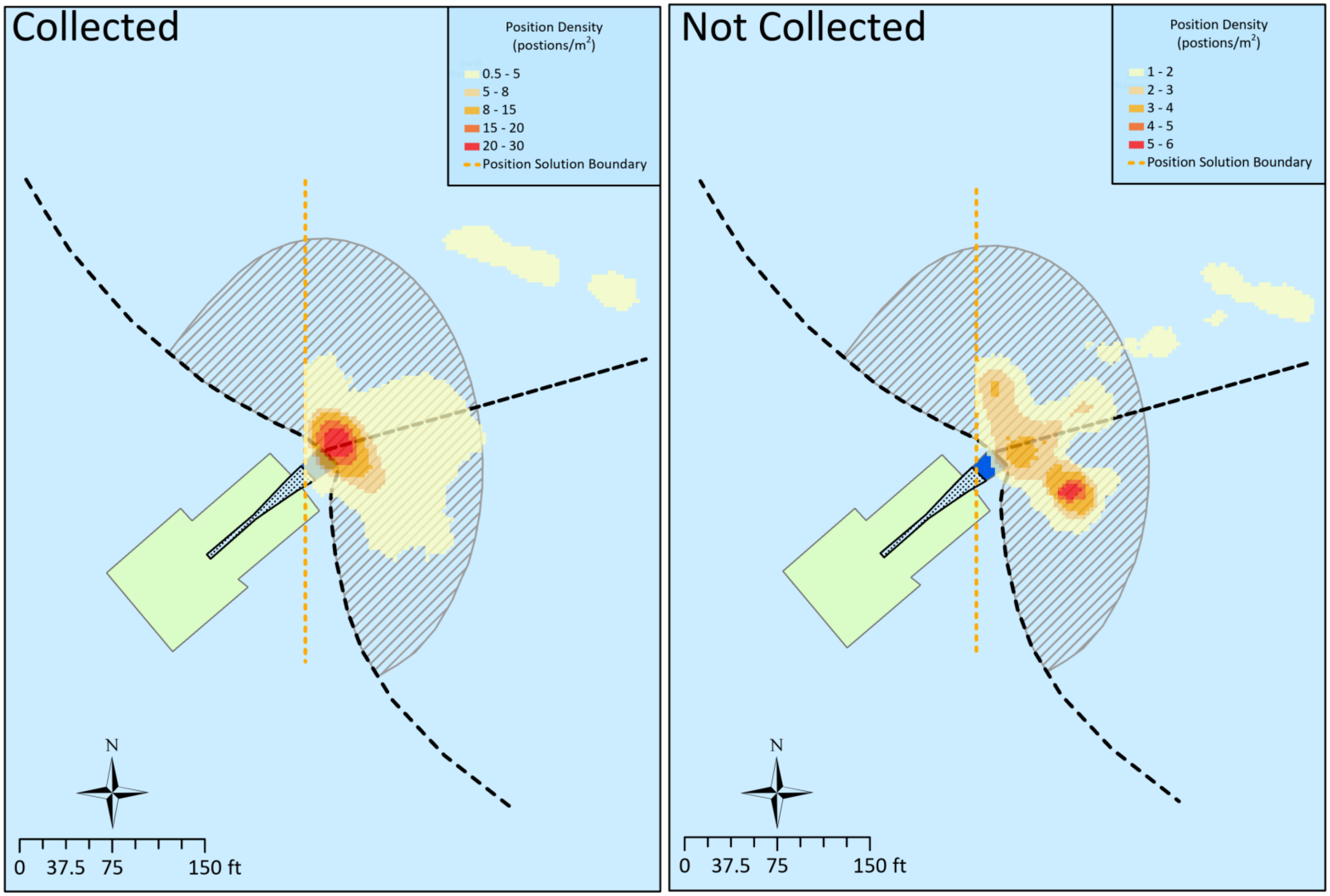

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Figure 13. Heatmap showing density of first positions within the zone of influence estimated for Chinook Salmon

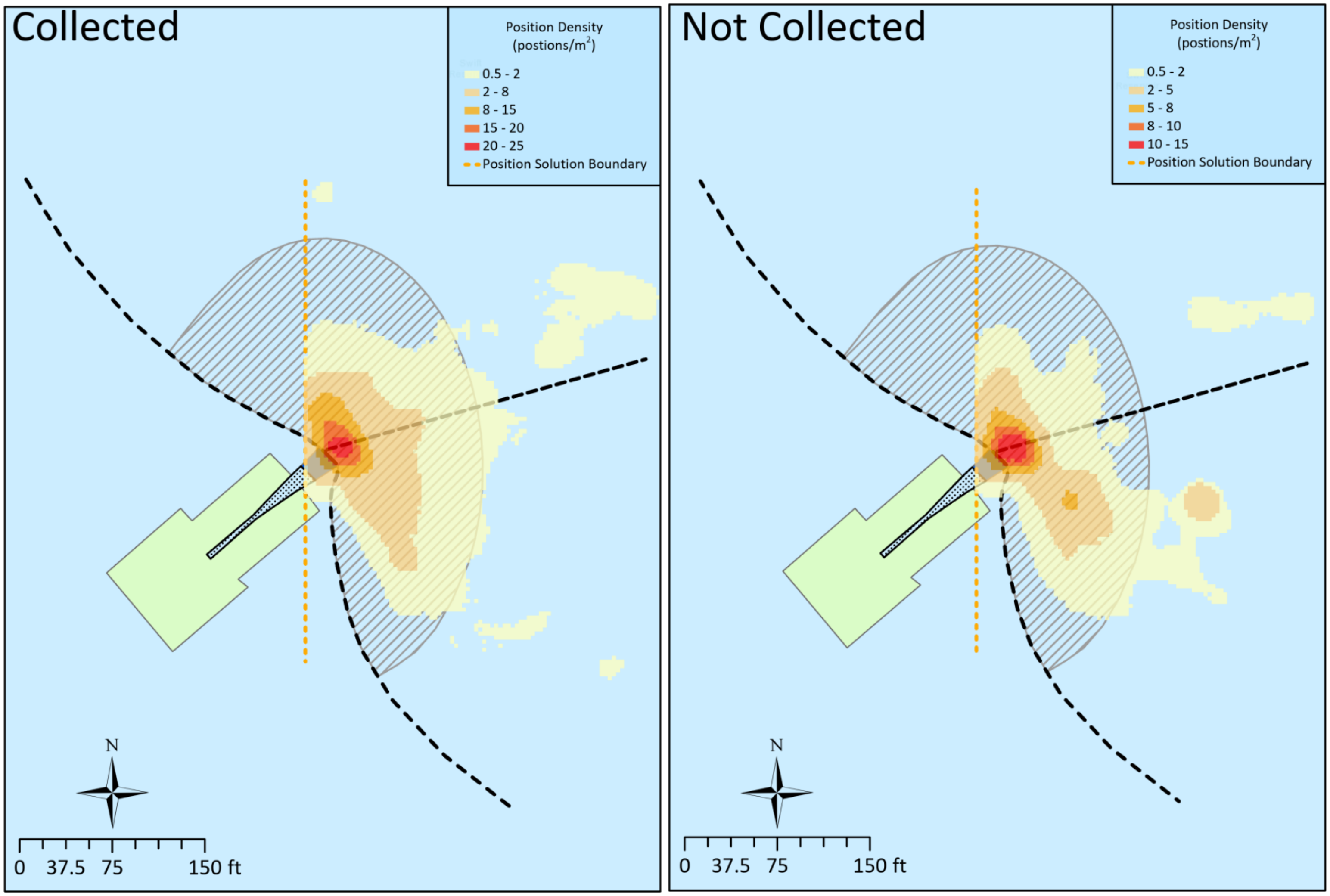

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Figure 14. Heatmap showing density of first positions within the zone of influence estimated for Coho Salmon

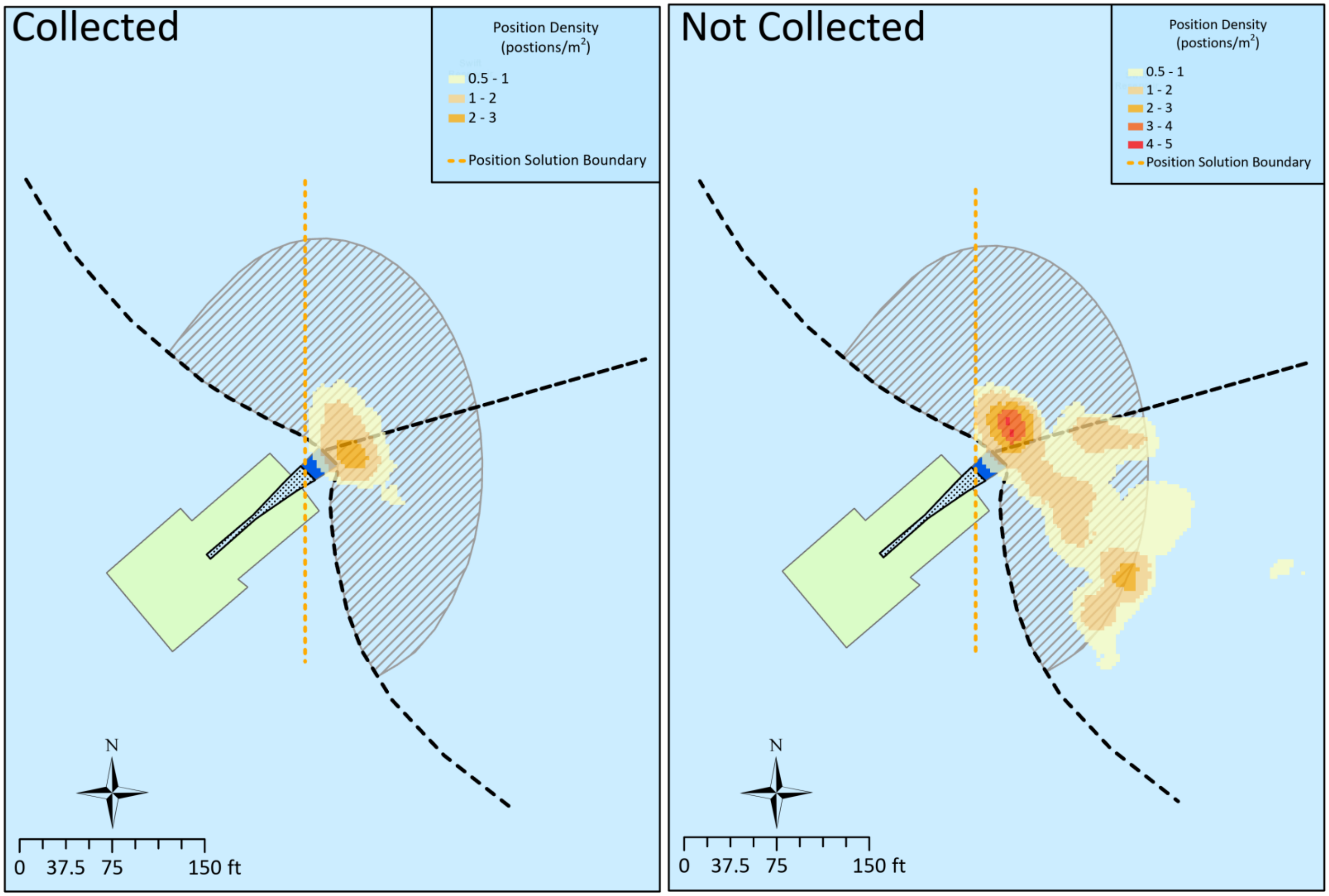

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Figure 15. Heatmap showing density of first positions within the zone of influence estimated for steelhead

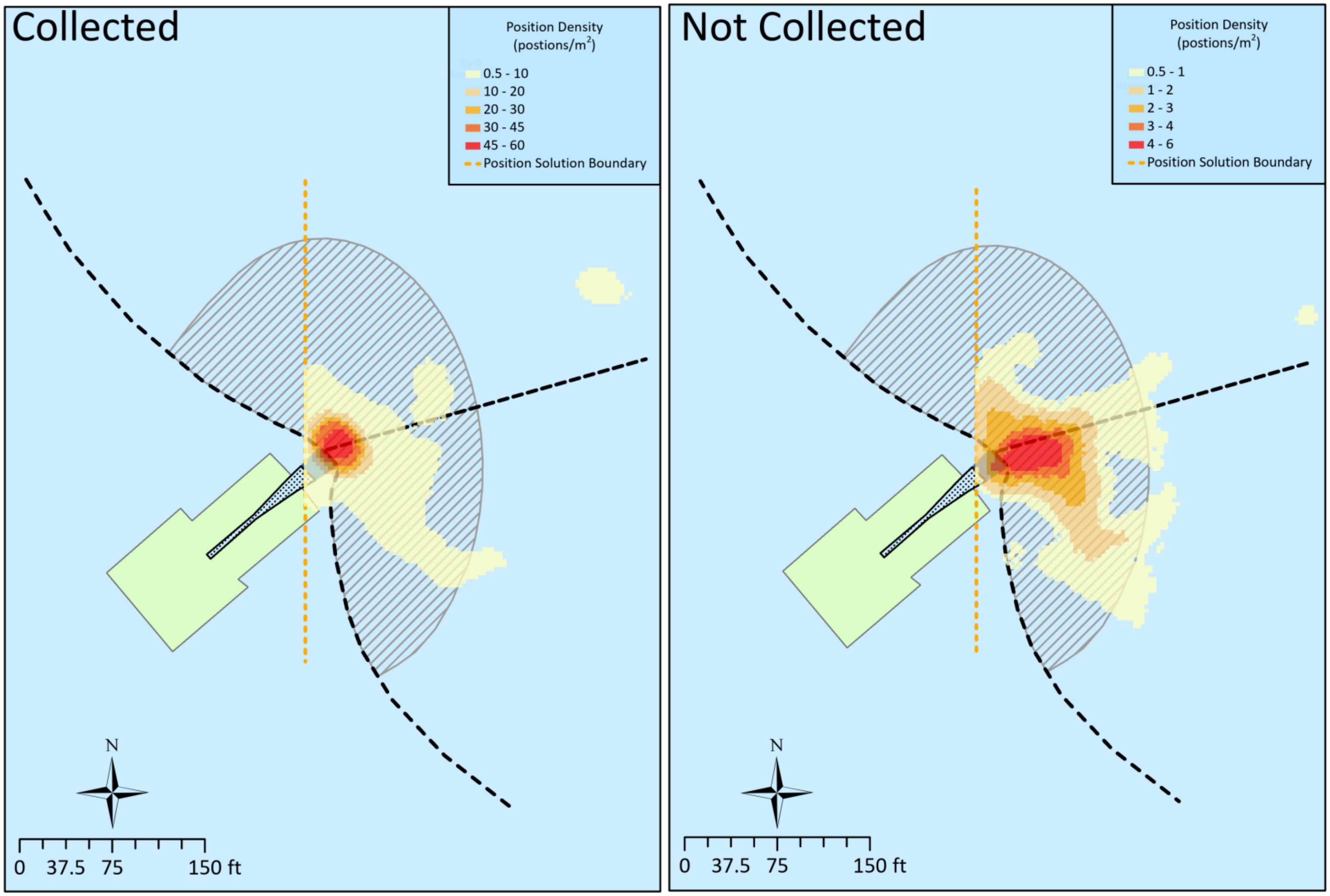

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Figure 16. Heatmap showing density of last positions within the zone of influence estimated for Chinook Salmon

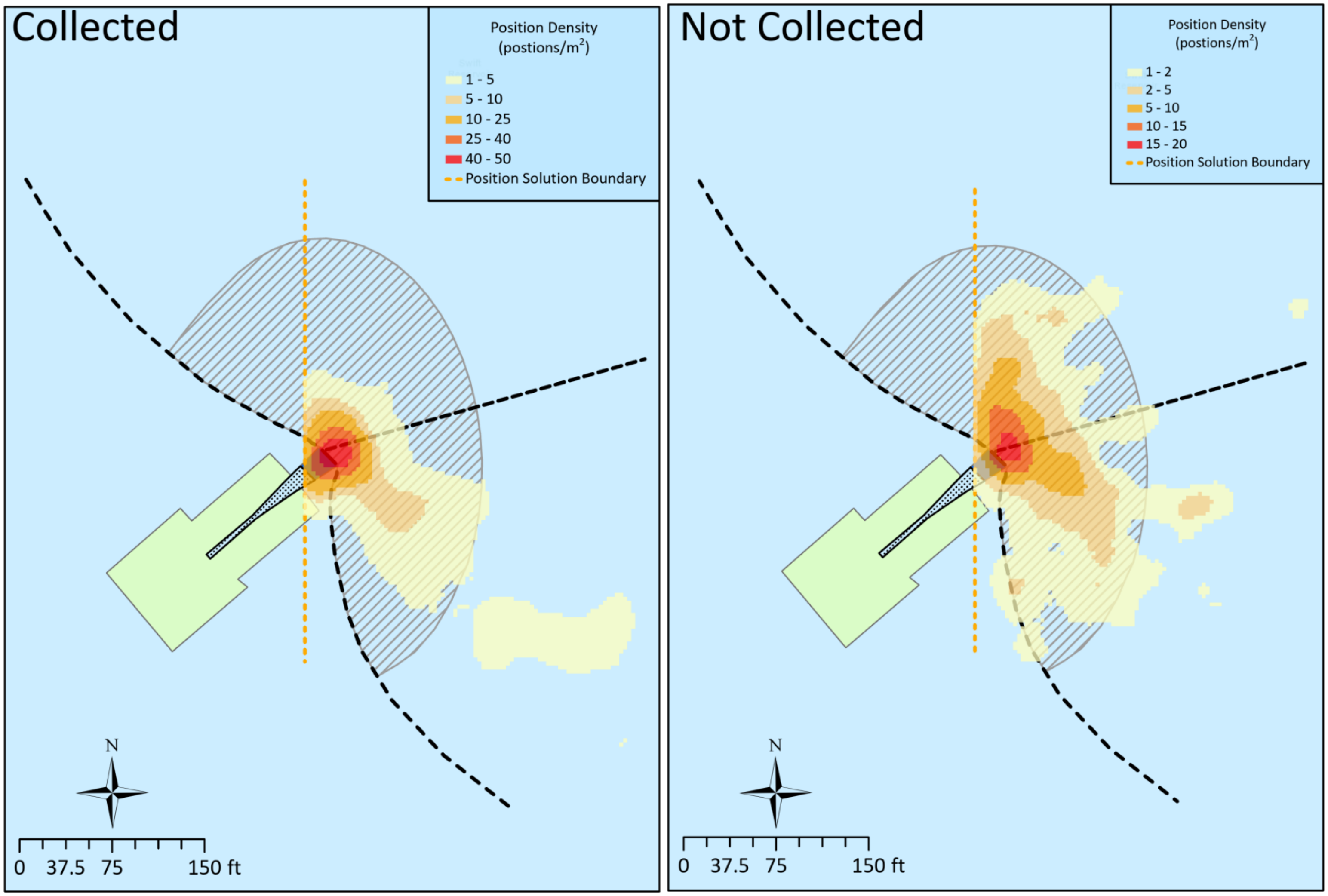

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Figure 17. Heatmap showing density of last positions within the zone of influence estimated for Coho Salmon

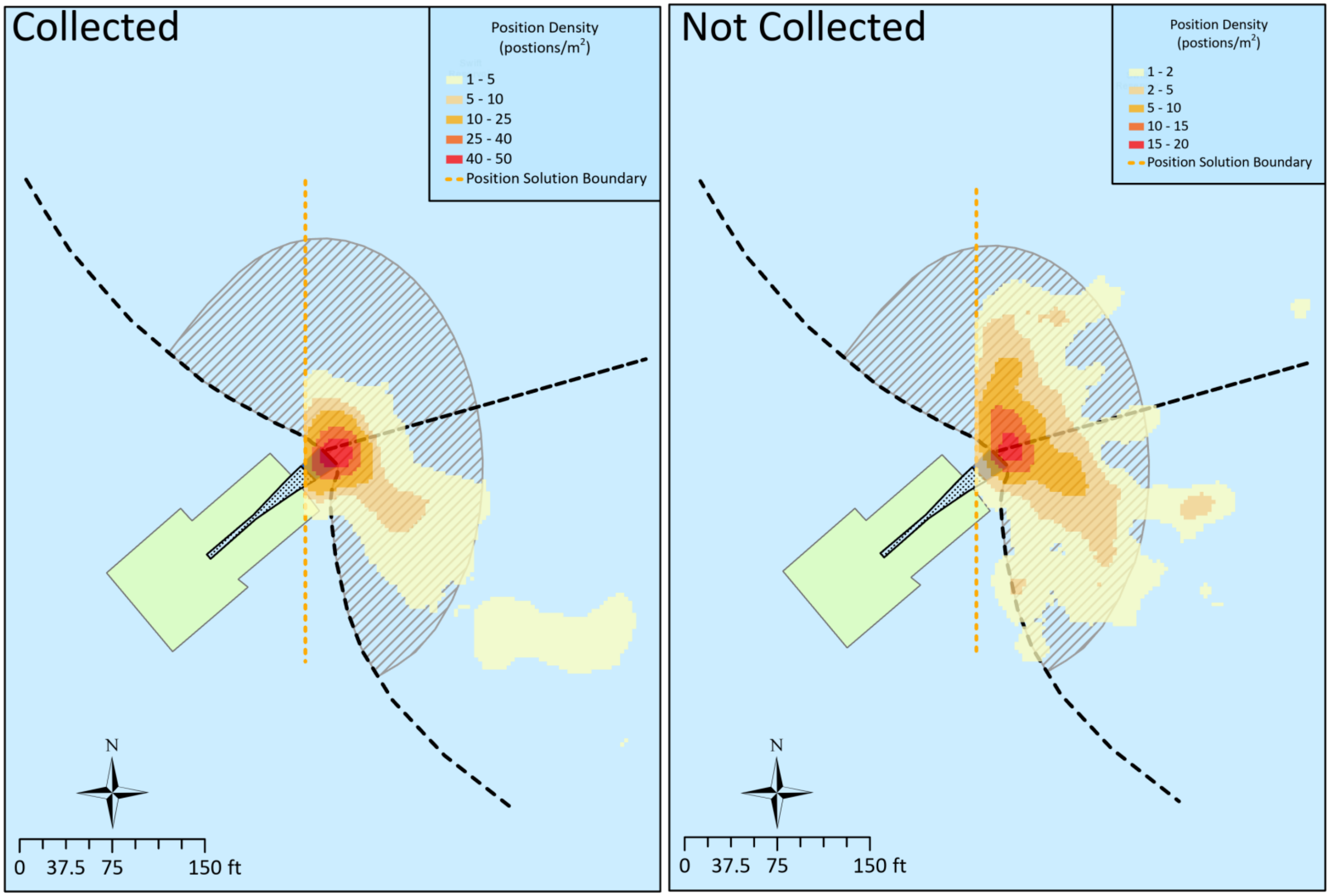

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Figure 18. Heatmap showing density of last positions within the zone of influence estimated for steelhead

3.3.4 Rejection Inside the Collector

Rate of rejection (i.e., an estimate of the ratio of fish within the collection channel that were never collected to the total number within the collection channel) was calculated for study fish detected within the collection channel of the FSC. Rejection was significantly different among species ($p < 0.01$), and greatest for steelhead (66.7%), followed by Coho Salmon (29.8%), and Chinook Salmon (13.6%) (Table 6). The median number of visits to the collection channel ranged from 1 for Chinook to 11 for steelhead, but the maximum number of visits per fish for all three species ranged to over 80 visits. The duration of each visit (i.e., specific events) ranged from 0.3 minutes to over 4.5 days (6,497.9 minutes), but typical visits lasted only a few minutes (median duration of each visit was 2.4 minutes across all species) (Table 7). Neither seasonal nor diel trends were observed in visit duration.

Table 6. Rate of rejection and number of visits in the collection channel at the Swift floating surface collector by species, 2019

Species	Number of Fish Detected in Collection Channel	Rate of Rejection (SE)	Number of Visits		
			Min	Median	Max
Chinook Salmon	44	14% (5.4%)	1	1	75
Coho Salmon	151	30% (3.7%)	1	6	61
Steelhead	30	67% (8.8%)	1	11	83
All	225	32% (3.1%)	1	4	83

Table 7. Duration of collection channel visits (minutes)

Species	Number of Visits to the Collection Channel	Duration of Visit (minutes)		
		Min	Median	Max
Chinook Salmon	228	0.3	3.2	914
Coho Salmon	1,546	0.4	2.4	6,498
Steelhead	513	0.3	2.4	122
All	2,287	0.3	2.4	6,498

Multivariate analyses of behavior within the collection channel supported related analyses previously described. A nominal logistic fit indicated that both the last week detected in the collection channel and length of study fish were significantly related to rejection, with larger fish later in the season having a low likelihood of collection (Table 8). The number of visits, species, and diel period were not significantly related to rejection in the model (all three $p > 0.20$) and release date was also unrelated to rejection ($p = 0.76$) (Table 8). The model demonstrates how the probability of rejection changes with these predictor variables. For example, a smaller Chinook Salmon (106 mm) making a visit to the collection channel earlier in the season (week 19) has a 70% lower probability of rejecting the collection channel compared to a larger (215 mm) fish that visits the collection channel later in the season (week 26). The size relationship is evident in steelhead, where the probability of rejecting the collector increases from 50% to 79% between fish at the first and third quartile in length (189 mm and 236 mm, respectively). In fact, none of the steelhead larger than 250 mm released for the study were recaptured.

Table 8. Effect summary for the logistic fit for collector rejection

Variable	P Value
Last Week Detected in Collection Channel	0.00001
Length	0.00013
Number of Visits to the Collection Channel	0.20
Species	0.24
Diel Period	0.26
Release Week	0.76

4 Discussion

This section discusses the general results of the 2019 Study, compares the results among study years, and addresses three principal questions related to the behavior and operation of the FSC.

In the 2019 Study, rate of reservoir passage (P_{RES}) was similar to the 2017 study in which fish from similar sources were used. Earlier studies reported higher P_{RES}, but fish from those studies were obtained through different methods that may explain these differences (Anchor QEA 2018). ZOI presence (P_{ENC}) was also similar to that reported in the 2017 study. However, rates of entrance efficiency, retention efficiency, and collection efficiency (P_{ENT}, P_{RET}, and P_{CE}) were substantially different than past study years, indicating that modifications to the collector made since the 2017 acoustic telemetry study may have influenced fish behavior.

4.1 General Comparison of 2019 Collection Efficiency Estimates to Previous Years

In 2019, P_{CE} estimates for all species were less than the performance goal of 95%. The total corrected P_{CE} estimate was 55% with individual species estimates ranging from 27% for steelhead to 63% for Coho Salmon. However, within the context of historical studies, the 2019 P_{CE} estimate across all species was higher in 2019 than any observed in previous studies between 2013 and 2017, which ranged from 6.7% (Courter et al. 2013) to 29% (Caldwell et al. 2016). Similarly, the 2019 P_{CE} estimates for Chinook Salmon (51%); and Coho Salmon (63%) were also higher than any observed in past studies where active tags (i.e., radio or acoustic telemetry tags) were used (Courter et al. 2013; Stroud et al. 2014; Reynolds et al. 2015; Caldwell et al. 2016; Anchor QEA 2018). In contrast, the estimate for steelhead was similar in 2019 to previous study years where dual PIT and acoustic tags were used (Courter et al. 2013; Stroud et al. 2014; Reynolds et al. 2015; Caldwell et al. 2016; Anchor QEA 2018), but was lower than the S_{RES} observed during the most recent 2018 PIT only study (PacifiCorp and CPUD 2019).

Between 2013 and 2016, the study design evolved considerably, moving from radio telemetry to dual PIT- and acoustic-tag-based studies, and has focused more closely on specific factors that influence P_{CE}. Starting in 2017, there were additional refinements including correction of metrics using detection efficiencies and fish source that affect comparability to previous years; however, study design and methods in 2017 were similar to those used in 2019. Water temperature in the reservoir was also similar in the 2017 and 2019 study years, enabling comparison between the 2017 and 2019 studies that enable conclusions to be drawn regarding the impact of modifications to FSC operation on P_{CE}. Results of the 2018 PIT-only study are also informative as they provide insight into the impact of successive modifications made in consecutive years after the 2017 study.

The FSC has undergone substantial modifications that may have improved P_{CE} since the 2017 study. During the 2017 study, it was determined that sound conditions in the water exceeded intensities within the frequency range that are thought to deter smolts (Anchor QEA 2018). In late 2017, FSC sorting area flow pumps were re-programmed to run at a lower rate in an effort to reduce underwater “noise”; reductions were confirmed by follow-up sound measurements. Operating noise reduction is thought to have contributed to the increased collection numbers observed in 2018 (PacifiCorp and CPUD 2019). Additional modifications were made prior to the commencement of the 2019 Study, primarily raising the floor of the NTS to reduce the cross-sectional area and increase attraction water velocity (from 0.5 fps to 1.4 fps) through the entrance of the NTS, and baffles along the primary screens in the collection channel were adjusted to further reduce operational noise in the collector (R2 2019). The combination of reduced operating noise and increased attraction velocity likely account for P_{CE} increases in Chinook and Coho salmon observed in spring 2019.

Steelhead P_{CE} was similar in 2017 and 2019. However, S_{RES} in 2018 was nearly two times higher than steelhead P_{CE} in 2019. This could suggest that operational changes made to the FSC after the 2018 PIT tag only study, may have reduced steelhead P_{CE} in 2019, though differences in handling (i.e., PIT tag only in 2018 vs. acoustic tagging in 2019) between the two studies may also be a contributing factor. Considering that fish condition and other environmental factors vary among years, a review of available information was conducted to see if there were any conspicuous or unique observations to explain the reduced steelhead P_{CE} in 2019. Anecdotally, there was some indication that steelhead from the run-at-large at the FSC were in poorer condition than previous years. Specifically, steelhead smolts appeared to be lethargic, relatively slender, and had copepods present (though copepod infected fish were not tagged) (Ferriaolo, personal communication, November 6, 2019). This may have contributed to lower P_{CE} in 2019 as compared to the derived value in 2018. Steelhead in the run-at-large were also generally larger in 2019 than any other year, small steelhead were not present in any number. This suggests low recruitment from the 2017 brood year; the year, which had the fewest females ever taken upstream in all other years of the program (Karchesky, personal communication November 19, 2019). The overall abundance of steelhead smolts was also lower in 2019 than in 2017 or 2018. For salmonids, abundance-driven schooling behavior is linked to migration patterns and predation risk that could alter P_{CE} (Hvidsten and Johnsen 1993). For example, in higher abundance years, the presence of large numbers of members of the same species could trigger migratory movement through the “pied-piper” effect (Weber and Fausch 2003) or potentially lower predation risks through swamping effects (Furey et al. 2016), both of which could contribute to higher P_{CE}. The low numbers of steelhead also impacted sample size for this study as there were not enough healthy fish available to meet target sample sizes (which was 155 steelhead).

Because steelhead exhibit wide variation in their fresh water life histories, and multiple year classes may outmigrate in a given year (Peven et al. 1994), analysis was conducted to find evidence that the observed behavior in 2019 could be a reflection of behavioral variation among the age classes represented in the 2019 outmigration year. While age data were not available for each smolt, length data were available and provided a coarse-scale surrogate for age. In general, it appears that larger, presumably older smolts were less likely to be recaptured. Moreover, steelhead smolts over 250 mm were never recaptured. However, the size distribution of steelhead in 2019 was similar to steelhead released during the 2017 and 2018 studies, so size/age alone is not likely to fully explain variation in steelhead P_{CE} among study years.

It is possible that larger smolts were less motivated to migrate because they were physiologically inclined towards residualism (Sharpe et al. 2007), or because their absolute size conferred better swimming performance (Bainbridge 1958) and allowed escape from entraining flows within the FSC. The former would be the result of the growth environment experienced by putative older fish but is impossible to evaluate without more information on age, growth, and physiological condition of the fish. If absolute size is driving the observed results, a finer resolution examination of flow velocities and spatial delineation of avoidance behavior among different size classes within the FSC would be needed to confirm the hypothesis. Because steelhead used in the study were larger in size than the other species, the hypothesized effect of absolute size may be more pronounced for steelhead, particularly the largest individuals. The role of fish size in the 2019 results is discussed in more detail within Section 4.2.

The explanations for higher P_{CE} among Chinook and Coho salmon may also have been related to the same factors that reduced steelhead P_{CE}. In 2019, the abundance of Coho Salmon smolts was substantially higher than that observed in 2017 and 2018 while the number of Chinook Salmon smolts was similar to previous years. Study Chinook Salmon in 2019 were smaller on average than those released in 2017 and 2018 though Chinook Salmon sizes were distributed more widely than in other study years. The average lengths of Coho Salmon were larger in 2019 than in 2017. This may have influenced migratory behavior and smolting process (Beckman et al. 1998); however, P_{RES} and P_{ENC} were similar for all species in both years, suggesting that both 2017 and 2019 study fish had similar motivation to migrate. Chinook and Coho salmon, on average, were smaller than steelhead and had very few individuals greater than 250 mm in length, which may also explain higher P_{CE}.

In both the 2017 and 2019 studies, fish entering the collector as far as the NTS were evaluated using the P_{ENT} performance metric, which examines the proportion of fish that moved from the ZOI and entered the NTS. Overall, the corrected P_{ENT} estimate for all species in 2019 was 93%, meaning that almost all of the fish that found the ZOI also entered the NTS at least once. When viewed on a species-specific level, both steelhead and Coho Salmon exhibited similar behavior with P_{ENT} of 97% and 98%, respectively. P_{ENT} of Chinook Salmon was lower at 78%, though still relatively high when compared to previous study years. Both the study-wide and species-specific P_{ENT} values were significantly higher than in 2017 (i.e., there was no overlap in the 95% confidence intervals).

Position density heatmaps tell a similar story with the density of positions in or in front of the NTS for both collected and not-collected fish (Figures 10 through 12). Density plots of the initial fish positions within the ZOI (Figures 13 through 15) are also concentrated in or in front of the NTS showing that fish are making directed movements towards the entrance of the NTS upon first entering the ZOI.

These results represent a 63% increase in P_{ENT} when compared to 2017 where fish were similarly positioned in the vicinity of the collector but failed to enter in large numbers (2017 P_{ENT} was 57% overall and 47%, 65%, and 49% for Chinook Salmon, Coho Salmon, and steelhead, respectively; Anchor QEA 2018). These observations support the conclusion that failure of fish to enter the NTS in 2017 was related in part to noise generated by FSC operation and that reducing this noise and increasing attraction flow velocity have been effective at encouraging fish to enter the NTS.

4.2 Are Fish Staying in the Collector and Being Captured?

Though most of the test fish entered the NTS, only a little over half of these were collected. The probability of collection after entering the NTS was evaluated using the P_{RET} performance metric, which examines the proportion of fish that moved from the NTS to collection. Overall, the corrected P_{RET} estimate for all species was 60%; in other words, 40% of the fish that entered the FSC did not proceed on to collection. The species specific P_{RET} in 2019 was 65% for Chinook and Coho salmon and 28% for steelhead. For Chinook Salmon this represents almost a three-fold increase over P_{RET} in 2017. Coho Salmon P_{RET} also increased; however, steelhead P_{RET} was lower than in 2017.

Given the high numbers of fish that entered the collector in 2019, the reach between the NTS and the weir at the end of the collection channel now appears to be the most significant bottleneck to reaching P_{CE} targets. Modifications to the FSC appear to have succeeded in encouraging fish to enter, but something inside in the collection channel is causing them to turn around. This behavior may be a response to increasing velocity changes or the constricting nature of the collection channel (Kemp et al. 2005;

Enders et al. 2009, 2012), additional noise (flow or operational) in the collector (Simpson et al. 2016), light conditions (Riley et al. 2015), or predation (Adams and Smith 2017). While each of these factors are plausible explanations for suboptimal transition rates within the collector, a test/control or focused evaluation to address these components individually has not yet occurred. Velocity patterns within the FSC do not show obvious trends that would promote rejection and are well within guidelines established by the National Marine Fisheries Service.

The most informative results for improving P_{CE} appear to be related to the size of the fish entering the facility. The size-dependent collection probability observed with the multivariate analysis indicates that larger fish had a higher probability of rejecting the collector after entering the collection channel. Specifically, given the fact that all species experienced the same collection environment but larger fish were significantly more likely to reject collection suggests that flow velocities within the FSC collection channel have an asymmetric impact on fish of different sizes that may be independent of species.

This “size effect” may be explained by larger fish being able to achieve burst velocities great enough to escape entrainment flows within the collector, and thus able to make multiple visits and avoid collection. The effectiveness of avoidance behavior as a means to avoid entrainment would reflect both the swimming capabilities of the fish and the velocity of entraining flows. In general, the maximum swimming velocity for a larger fish is higher than for a smaller fish of the same species (Bainbridge 1958) so it follows that larger smolts may be able to more effectively escape entraining flows within the FSC if the avoidance behavior is initiated at the same location within the collector. This may explain why steelhead P_{RET} declined at the same time that Chinook and Coho salmon P_{RET} increased: test steelhead were generally larger than other test fish and while increased attraction velocity encouraged fish of all sizes to enter the collector, larger fish were able to escape when faced with a condition that elicited an avoidance response.

Collection time was related to time of day for Chinook Salmon with the majority of collection events for that species occurring at night. This finding is consistent with other studies that have found interactions between light levels and flow velocity. Haro et al. (1998) noted that downstream migrating juvenile Atlantic Salmon exhibited strong behavioral responses to accelerating flow fields within a weir entrance. At a “critical reaction point” within the weir, fish either continued to pass or swam rapidly upstream to avoid entrainment. Most smolts were able to burst swim upstream to avoid entrainment at velocities less than 2m/s; however, at very low light levels, smolts rarely swam upstream. Vowles et al. (2014) also observed avoidance behavior by Chinook Salmon smolts when they encountered velocity gradients in an experimental flume. Similar to Haro et al. (1998), lighting modulated the behavioral response where avoidance behavior increased when the flume was illuminated and decreased when it was dark.

Lighting may also influence juvenile salmonid migration behavior, and therefore collection efficiency, through the creation or elimination of visual cues (Haro et al. 1998). In general, light is necessary for visual predators to acquire prey and therefore contributes to diel outmigration behavior patterns among salmonid smolts to avoid predation (Ibbotson et al. 2006). Light is also necessary for creating shade, which can in turn alter the spatial distribution of smolts away from overhanging structures or riparian cover, presumably as an adaptive response to predators occupying shaded habitats (Kemp et al. 2005, 2008). Light also contributes to the ability of juvenile salmonids actively orient to flow through visual detection of movement relative to adjacent habitat features (Thorpe et al. 1988). Changes to the FSC that alter the perception of light by juvenile salmonids should therefore be considered as potential tools to improve collection efficiency. For instance, it may be possible to illuminate structural components of the FSC that are causing shading, or minimize the visual perception of movement by ensuring that the floor and channel of the FSC are visually homogenous (i.e., eliminate strong contrasting visual elements that would allow fish to easily detect that they are “moving”).

The effect of light or darkness on the behavior of salmonids may, however, differ among species. As an example, juvenile Chinook Salmon tend to migrate deeper during the day and shallower during twilight and evening periods, whereas steelhead tend to be surface oriented during the day and occupy deeper habitats at night (Li et al. 2018). It follows that increasing shade or lighting in the vicinity of the FSC could influence the vertical distribution of migrating fish but not necessarily in the same direction for all species. The interactions among modified lighting/shading, vertical distribution, and avoidance behavior within the FSC are potentially complex but may provide an additional opportunity for improving collector efficiency.

4.3 Conclusions

Of the 279 juvenile salmonids that were detected in the ZOI, 254 were detected entering the NTS and in many cases progressing forward into the collection channel. Over 90% of the fish in the ZOI entered the collector and 40% of these were not collected. These results indicate that modifications to the collector since 2017 have been effective at encouraging fish to enter the collector and current bottlenecks to achieving collection goals are caused by avoidance responses in the collection channel. Future studies focused on fine scale movements within the NTS and collection channel could help identify potential reasons fish are rejecting the collector after entering and may identify the locations in the collection channel where fish are making upstream movements.

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APPENDIX A Study Methods

Study Methods

The following study methods were used for the 2019 Swift Reservoir Floating Surface Collector Passage Evaluation in order to collect and analyze data to inform decisions related to the operation and performance of the floating surface collector (FSC) relative to multiple performance metrics.

A.1 Acoustic Receiver Configuration

A variant of the “greedy” heuristic optimization search procedure (Cormen et al. 2009) was used to evaluate the performance of numerous array configurations before a final array configuration was selected for field testing. The search procedure uses a set of randomly simulated (hypothetical) fish positions. For a given array configuration, the actual time of arrival for each of hypothetical position is known. To simulate field conditions, random noise is added to each signal and the position of the signals are solved for various array configurations. An optimal array configuration is then determined that minimizes the error between the estimated and known signal positions.

The approach above was applied to the Swift reservoir by imposing site-specific constraints on the optimization procedure by limiting the search for receiver locations to feasible array deployment locations. The search procedure was initialized with the configuration of the acoustic receivers in the net transition structure (NTS) and zone of influence (ZOI) that was used in 2017 study (Anchor QEA 2018). A set of 30 randomly simulated positions within the ZOI were used assess the position accuracy of the configuration. To simulate field noise, random noise was added to the time of arrival that translated to spatial error of approximately 3 meters. The heuristic procedure was then used to successively refine the array configuration by minimizing the error in the estimated hypothetical positions.

Field testing was initialized with the 2017 array configuration by moving acoustic beacon tags through the ZOI with a hand-held GPS that provided the coordinates at a number of locations. The resulting detection data were processed to estimate detection efficiency and 3D position accuracy of the array relative to the known GPS positions. The receivers in the array were then repositioned to the optimum array configuration described earlier. A second field test with the acoustic beacon tags was performed and the detection data were processed in the same manner as the first test. A comparison of the 3D position estimates confirmed that the optimal array configuration represented an improvement in the 3D position accuracy over the 2017 array configuration. Minor refinements to the receiver array configuration were necessary to accommodate site-specific conditions. The final receiver array configurations are provided in Table A1.

Table A1. Receiver and beacon positions during deployment and surveying for the 2019 study

Receiver Name	Receiver ID	Beacon Code	Hydrophone Depth (feet)	Beacon Depth (feet)	Latitude (DD)	Longitude (DD)
ZOI-01	SR18133	G721F14A8	74	77	46.06186489	-122.1937873
ZOI-02	SR18158	G727DBEB2	15	18	46.06193554	-122.1934024
ZOI-03	SR18129	G727DADCD	90	93	46.06186181	-122.1930464
ZOI-04	SR18159	G721F1BE9	25	29	46.06159973	-122.1932222
ZOI-05	SR18152	G721F3EF5	90	93	46.06136915	-122.1933962
ZOI-06	SR18131	G727DAA4E	20	23	46.06171539	-122.193978

Receiver Name	Receiver ID	Beacon Code	Hydrophone Depth (feet)	Beacon Depth (feet)	Latitude (DD)	Longitude (DD)
ZOI-07	SR18134	G727DA9AC	10	13	46.06174884	-122.1941479
ZOI-08	SR18160	G727DB1F3	26	23	46.06180812	-122.1942134
NTS-09	SR18130	--	10	--	46.0617501	-122.1942964
NTS-10	SR18146	--	8	--	46.06171579	-122.1942652
DBB North	SR19016	G72381F27	25	25	46.06277887	-122.1903568
DBB Central	SR19014	G721F2077	25	25	46.06173349	-122.1906068
DBB South	SR19015	G721F68F3	25	25	46.06039405	-122.1903919
NTS Upstream Beacon	--	G721F7AD2	--	6	46.06176159	-122.1942273
NTS Downstream Beacon	--	G721FDF42	--	2	46.06172992	-122.1942797

Notes:
Receiver positions were surveyed during initial deployment. Receivers moved during deployment due to wind and water level fluctuation. Real time positions were recorded and corrected with GPS units in ATS receivers. Depths are given in feet and coordinates are given in decimal degrees (DD).

A.2 Receiver Data Download and Maintenance Schedule

After initial receiver deployment during the week of February 18, 2019, data were downloaded from all receivers on as close to a bi-weekly schedule as possible (Table A2). This schedule was partly dependent on weather, boat availability, and unanticipated receiver maintenance requirements. There were two unanticipated maintenance tasks that occurred while the array was deployed. The first occurred early in the season in response to unexpected ambient noise in the NTS and resulted in several unplanned maintenance events between March 18 and April 2. Work during these events included identifying the source of the ambient noise and reconfiguring receivers to minimize the impact of the background sound on the ability to detect and position fish within the NTS. The source of the ambient noise was determined to be flow related and likely caused by increased flows in the NTS. The ultimate resolution was that hydrophones on the NTS (ZOI-07, ZOI-08, NTS-09, and NTS-10) were repositioned out of the main flow vectors. The second unanticipated maintenance event occurred on May 23. Work consisted of an update to the firmware on all receivers in order to correct an intermittent time shift issue that was identified early on during in-season data processing. The issue was a result of an error in the receiver firmware installed by the vendor (ATS), which altered the internal clock on the receiver to revert backwards in time until a GPS signal corrected the time jump. All data impacted by these time shift issues were corrected during post-processing (as described in Section A.3), and subsequent data processing indicated the issue was corrected by the updated receiver firmware.

Table A2. Receiver data download and maintenance schedule for the 2019 study

Date	Receiver Data Downloaded	Other Activities
2/18 - 2/22		Deployed and tested acoustic telemetry array
3/8	All receivers	
3/15	ZOI-07, ZOI-08, NTS-09, and NTS-10 receivers	
3/18		NTS receiver testing

Date	Receiver Data Downloaded	Other Activities
3/21		NTS receiver testing
4/2		Repositioned ZOI-07, ZOI-08, NTS-09 and NTS-10
4/11	All receivers	
4/19	ZOI-07, ZOI-08, NTS-09, and NTS-10 receivers and forebay array receivers	
4/23	All receivers	
5/1	NTS and ZOI array receivers	
5/10	All receivers	
5/20	Forebay array receivers	
5/23	All receivers	Updated firmware all receivers
5/28	All receivers	
6/4	All receivers	
6/21	All receivers	
7/10	All receivers	
7/22	All receivers	Demobilized telemetry array

A.3 Time Correction

A subset of the collected acoustic data from both the SR3017 and SR3001 acoustic receivers required post-hoc time correction due to an issue with the receiver's firmware. Time shift issues were eliminated following a firmware update during field maintenance on May 23.

To correct time shifts present in the acoustic detection data prior to the firmware update, beacon tag detections associated with the time-corrupted acoustic receiver were used as a reference point for estimating the magnitude of the time shift and correcting the time relative to known accurate detected beacon times. First, the ping rate of the reference beacon was calculated from the data collected prior to the time shift. This ping rate was then used to estimate when the next beacon transmission was expected to occur following the time shift. Comparing the expected time to the recorded time provided the magnitude of the time shift. The beacon and study tag detection times were then corrected using the magnitude of the time shift determined in the previous step of the process.

A.4 Fish Positioning Algorithm

The fish positioning algorithm uses a non-linear solver (Heath 2002) to minimize the error between the estimated and observed time difference of arrivals. The relevant time of arrival and error minimization equations are defined in Deng et al. (2011). In the horizontal direction, the range of potential position solutions are constrained to be within a rectangular area that are dependent on the anticipated maximum detection range of the outermost receiver in each direction. Vertically, the algorithm is constrained in its search between the maximum depth of the forebay and the water surface. The speed of the acoustic signal in water used in time of arrival calculations was estimated following the methodology in Marczak (1997), where temperature was taken as the observed temperature on the receiver at time of acoustic detection, or as the average temperature during the corresponding analysis period across receivers ZOI-02 and ZOI-04 when receiver specific temperature data were unavailable. Once positions were constructed, a secondary filter was applied to remove any positions that appeared unreasonable based on the locations of previous and consecutive positions and the estimated average speed of a fish. This filtering was necessary in order to omit spurious positions that may have been resolved by the algorithm but had a high degree of uncertainty relative to the entire position solution set.

The final position data were partitioned into positions constructed for beacon tags and positions constructed for acoustic tags implanted in study fish. Beacon tag positions were used to evaluate the accuracy of the positioning algorithm (as described in Section A.5), while study tag positions were read into GIS software and used in collection efficiency metric calculations and subsequent behavior analyses (as described in Sections A.6, A.7, and A.8).

A.5 Positioning Accuracy Diagnostics

The accuracy of positions was evaluated by comparing the estimated coordinates of each beacon tag with the position recorded by the GPS unit installed on the receiver to which the beacon was attached. These comparisons were performed on all data retrieved from the field for receivers ZOI-01 to ZOI-08 (Table A-2; data for some shorter download periods were combined for efficiency). NTS-09 and NTS-10 receivers were excluded as these receivers were not equipped with a beacon tag. The forebay array receivers were not used in 2D position estimation and beacons deployed to forebay array receivers were outside the position solution domain, thus beacons on those receivers were not evaluated. For the April 11 and May 10 data download periods, GPS and acoustic data were not available for receivers ZOI-08 and ZOI-03, respectively, due to technical issues occurring on the GPS and memory units of these devices, which compromised the accuracy of acoustic data. Data from these receivers were not used for positioning during the April 2 to April 11 and April 23 to May 10 periods, and redundancy in the acoustic array mitigated this omission so that the overall accuracy of positions during these periods was unaffected.

Estimated coordinates for each beacon tag signal were paired with GPS coordinates by averaging all GPS coordinate readings occurring on the beacon tag's receiver within a 2-minute window of the date-time of each beacon tag position. Coordinates were converted to Easting and Northing values within the Universal Transverse Mercator (UTM) coordinate system, and comparisons of the GPS position to the beacon position estimated by the positioning algorithm were plotted by time (Figures A1 through A16) and with respect to each other (Figures A17 through A32) to illustrate temporal and spatial patterns in the positioning algorithm's accuracy. Analysis of these diagnostic figures illustrate various factors affecting the accuracy of 2D positions, including diurnal and seasonal patterns in receiver movement (likely due to wind patterns and turbine operation), the mobility of receivers based on their location in the reservoir, and noise ratios around receiver accuracies due to the array configuration and noise produced by the collector. These diagnostics illustrate that despite receiver mobility and noisy ambient conditions, the approach used was able to position acoustic tags with an acceptable level of accuracy for the purposes of the study.

A.6 Performance Metric Calculations

Filtered acoustic detection data were used in conjunction with the finalized position data to determine zone presence of tagged fish in the calculation of collection efficiency performance metrics (Figure A33). After positions were estimated for study fish, position data were spatially analyzed using ArcGIS Pro 2.4.2 (ESRI 2011). Spatial representations of the ZOI and the NTS were constructed to spatially analyze the prevalence of estimated fish positions within each zone. The ZOI boundary was defined by an arc with a 150-foot radius centered on the midpoint of the northeast face of the collector and extended to include the approach routes along the barrier nets. The NTS boundary was constructed by creating a rectangular polygon whose vertices were defined by the initial deployment locations of receivers ZOI-07, ZOI-08, NTS-09, and NTS-10 (which were positioned at roughly the four corners of the NTS) and then buffering this polygon by a width of 3.5 meters. Buffer width was based on the approximate error between the estimated 2D beacon positions and the GPS positions for the ZOI-07 receiver across all analysis periods.

Zone presence in the forebay, ZOI, and NTS was defined as follows (see Table 2 in main text for reference):

- DET_{Swift}: an individual fish was considered to be within the Swift forebay array if it had at least one detection on any of the three autonomous forebay receivers (DB North, DB Central, or DB South) within the acoustic data after filtering out false detections.
- DET_{ZOI}: an individual fish was considered to be within the ZOI if it had at least five positions within the ZOI boundary within a 10-minute interval (Figure A33). This threshold was used in order to omit tags that may have had spurious positions within the ZOI.
- DET_{ENT}: an individual fish was considered to be inside the entrance of the NTS if it had at least one position within the NTS boundary and there were at least 16 occurrences of a tag's acoustic signal being detected on NTS-09 or NTS-10 first with a sufficiently high amplitude (213 or above based on the relative scale used on ATS receiver firmware). This additional filter was designed heuristically and verified the individual was in proximity to these receivers. This allowed for a weight-of-evidence approach that provided increased resolution in determining presence in the NTS that was not possible using 2D positions alone.

The software program MARK was used to construct a mark-recapture model from a presence-absence matrix constructed by the data (Cooch and White 2009). In order to meet the assumptions of the mark-recapture model, for each zone of analysis (the forebay, ZOI, NTS, and "collection"; Figure 5 of main text), no individual was considered present in the zone if they were not present in the preceding zone. Detection inefficiencies within each zone were then calculated by the software from those individuals that were detected in a zone and were not detected from the preceding zone. Confidence intervals for collection efficiency metrics were constructed using the profile likelihood approach where appropriate.

A.7 Fish Positions and FSC Approach Direction Analysis

Fish position data were summarized by species and collection status to analyze the general position of individuals as well as their arrival into the ZOI and their approach into the FSC. Position data were partitioned by species and collection status (i.e., collected vs. not-collected). Each partition was used to construct a raster grid using the Point Density geoprocessing tool within the Spatial Analyst package in ArcGIS to calculate position densities. This raster file consisted of 1-square-meter grid cells where each cell's value was equal to the density of positions within a 5-square-meter circle centered around each grid cell. The output raster was then symbolized, with densities lower than 0.5 positions per square meter being omitted from the map to more clearly illustrate high density areas where fish congregated. In this approach, each position is weighted equally regardless of whether the fish traversed the ZOI quickly generating few points or traversed it slowly generating many points.

A.8 Rejection Inside the Collector Analysis

The proportion of fish that entered the collector and subsequently exited was analyzed to examine rejection rates across species, collection statuses, temporal (i.e., seasonal and diel) patterns, and morphological characteristics. This approach focused on using a combination of raw detection data, position estimates, and passive integrated transponder detections within the collector to quantify the periods during which individuals were present in the collection channel. The analysis began by considering the data set of positions constructed by all individuals throughout the entire study period. For each of these individuals, a time series of presences within the ZOI and forebay was constructed based on the criterion described above. Entry and exit times for the NTS were determined using position estimates and a filter that was based on the position accuracy of beacon tags deployed throughout the season within the collector. This filter was established by observing that beacons deployed within the NTS were successfully positioned within the NTS by the positioning algorithm 92% of the time within a 20-minute window (i.e., the length of time it would take to generate 20 beacon tag emissions) and translating that to the study tag ping interval (i.e., 20 tag emissions in 1 minute).

For each period between intervals when an individual was thought to be within the NTS, the raw acoustic data were analyzed to identify a pattern in acoustic detections that suggested the fish was within the collection channel. This acoustic “signature” consisted of a period of relative silence during which the signal transmitted by the tag was only heard sporadically by at most one receiver for an extended period during which multiple continuous transmittals are expected. If this signature was found within the raw data, the individual was considered to have held in the collection channel between the times it was positioned within the NTS.

From this analysis, a dataset was constructed that contained the periods each individual was within the collection channel. Fish that were collected (and had active acoustic tags) were also separately analyzed by searching the raw data for the same acoustic signature and quantifying the period during which these individuals made their final traverse through the collection channel and into the collector. This generated a total of 225 individuals who were considered to have entered the collection channel at some point during the study period. From this dataset, the times and dates during which individuals moved into the channel were examined to inform the results on diurnal and seasonal patterns in collector rejection. Data on length were also combined to examine rejection likelihood across species and at different lengths.

References

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Appendix Figures A1 – A33

[*provided with pdf*]

APPENDIX B Summary of Results from Previous Swift Floating Surface Collector Collection Efficiency Studies Conducted Between 2013 and 2019

Table B-1. Summary of results from previous Swift floating surface collector collection efficiency studies conducted between 2013 and 2019

Study Attributes						Detection Numbers (Total)			Detection Estimates (Total)[1]				
Year	Study Type	Capture Location	Release Location	Species	Release Numbers	Detected Forebay	Detected ZOI	Captured at FSC	P_{RES} Estimate (%)	ZOI Detection Rate (%)	P_{ENT} Estimate (%)	P_{RET} Estimate (%)	P_{CE} Estimate (%)
2013	Radio Telemetry	FSC	<3.1 miles east of FSC	Chinook Salmon	58	NA	46	0	NA	79.3	NA	NA	0.0
				Coho Salmon	82	NA	44	6	NA	53.7	NA	NA	6.0
				Steelhead	NA	NA	NA	NA	NA	NA	NA	NA	NA
2014	Radio Telemetry	FSC	2 miles east of FSC	Chinook Salmon	20	NA	3	0	NA	15.0	NA	NA	0.0
				Coho Salmon	157	NA	31	9	NA	19.7	NA	NA	29.0
				Steelhead	16	NA	4	1	NA	25.0	NA	NA	25.0
2015	Dual PIT/ Acoustic Telemetry	Eagle Cliff Rotary Screw Trap/Hook and Line	Eagle Cliff	Chinook Salmon	14	9	6	0	64.3	42.9	NA	NA	0.0
				Coho Salmon	139	126	110	13	90.6	79.1	NA	NA	11.8
				Steelhead	47	43	43	8	91.5	91.5	NA	NA	18.6
2016	Dual PIT/ Acoustic Telemetry	FSC and Eagle Cliff Rotary Screw Trap	Eagle Cliff	Chinook Salmon	3	1	1	0	33.3	33.3	NA	NA	0.0
				Coho Salmon	156	140	98	30	89.7	62.8	NA	NA	30.6
				Steelhead	40	28	17	4	70.0	42.5	NA	NA	23.5
2017	Dual PIT/ Acoustic Telemetry	FSC	Eagle Cliff	Chinook Salmon	108	75	62	7	69.4	82.7	46.8	24.1	11.3
				Coho Salmon	232	184	164	46	81.0	91.6	65.1	41.1	26.7
				Steelhead	180	117	107	21	66.7	89.2	48.6	40.4	19.7
2018	PIT	FSC	Eagle Cliff	Chinook Salmon	396	--	--	94	--	--	NA	NA	23.7[2]
				Coho Salmon	484	--	--	191	--	--	NA	NA	39.5[2]
				Steelhead	278	--	--	136	--	--	NA	NA	48.9[2]
2019	Dual PIT/ Acoustic Telemetry	FSC	Eagle Cliff	Chinook Salmon	155	88	75	42[3]	62.8	85.2	78.1	64.9	50.7
				Coho Salmon	300	175	167	156[3]	85.9	95.4	98.3	64.6	63.5
				Steelhead	70	40	37	11[3]	62.8	92.5	97.3	27.8	27.0

Notes:
Source: Courter et al. 2013; Stroud et al. 2014; Reynolds et al. 2015; Caldwell et al. 2016; Anchor QEA 2018; PacifiCorp and CPUD 2019
1. For 2013 through 2017, seasonal performance metrics have been corrected for array detection efficiency.
2. In 2018, survival probability through reservoir (S_{RES}) was used as a surrogate for collection efficiency.
3. In 2019, there was a total of 209 study fish collected; however, only fish with active tags were used in the calculation of collection efficiency metrics.
-- = not calculated
NA = not applicable

APPENDIX D

MERWIN ADULT TRAP EFFICIENCY EVALUATION (WINTER STEELHEAD) – 2019 FINAL REPORT

Comment Matrix: Adult Trap Efficiency (ATE) Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee October 28, 2019.

Commenter	Comment Number	Location	Comment	Response
Kale Bently WDFW	1	Page iii Table 1	Similar to my comment in the results section, I am a bit confused as to why you are reporting Bayesian Credible Intervals but simultaneously reporting the "raw" point estimates. I realize it doesn't change the estimates by much: - all steelhead: 84% vs. 91%, - non-naïve: 85% vs. 88% - Naïve: 95% vs. 95% - Non-naivePF: 78% vs. 77% However, it seems a bit odd given that you have Bayesian derived summary metrics.	Understanding is that criteria based on raw estimates.
Kale Bently WDFW	2	Page iii Table 1	Is this number not closer to 20%? Trapped = 40, Captured = 32; Ti = (T – C) / T	Yes. Number was reported correctly in results section but erroneous here. Corrected.
Kale Bently WDFW	3	Page iv Line 78	Curious, are there precision targets for these estimates. Not saying it's the case here but this statement could be a bit misleading with low sample sizes.	Percision targets are not fully defined.
Kale Bently WDFW	4	Page iv Line 86	What is significance based on? Given that the actual capture percentages for the difference groups are listed above, I'm not sure this bullet is necessary	Bayesian tests for differences in proportions
Josh Ashline NMFS	5	Page iv Line 96	This is a speculative statement. You provide proof later in the report that trap outages increased the residence times.	Adjusted text to be more assertive. ("may" -> "appear to")
Josh Ashline NMFS	6	Page v Line 113-5	This is a great summary sentence. To me we know where to focus efforts to improve ATE.	Agreed. Trap lift and conveyance system reliablity appears to the largest effect on tailrace residency times.
Kale Bently WDFW	7	Page v Line 140	Not entirely how to assess this as I don't know what is considered a site, how many sites there are in total, and where they are all located.	Added clarification that this refers to radio telemetry receiver sites
Josh Ashline NMFS	8	Page vi Line 166-8	I agree. Just need to figure out ways to increase N. Explore additional/new sampling techniques over angling. Fish wheel?	It is unlikely that a fish wheel would be feasiable in the lower Lewis River, however other options like increased angling effort could be considered in the future.
Josh Ashline NMFS	9	Page 3 Line 500	This acronym is not defined in the Report I'm assuming Cramer Fish Sciences. However its only used twice I suggest spelling out each time to avoid confusion with cfs (cubic feet per second)	Defined CFS as Cramer Fish Sciences

Comment Matrix: Adult Trap Efficiency (ATE) Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee October 28, 2019.

Commenter	Comment Number	Location	Comment	Response
Josh Ashline NMFS	10	Page 4 Line 549-51	I appreciate the addition of this objective, but have some reservations about the HBCS reporting.	Noted. Added clarifying content regarding intent of this objective.
Josh Ashline NMFS	11	Page 5 Line 552	You should discuss the anesthetic(s) used for Naïve vs non-naïve fish. This is likely a major contribution to the stress related hypothesis.	Potentially. Naïve fish were suddated using a shadow box, whereas non-naïve fish were suddated using electro-narcosis (EA Basket)
Kale Bently WDFW	12	Page 5 Line 555	Added radio tagged to differentiate from blank wire tag.	Change accepted
Kale Bently WDFW	13	Page 5 Line 565	List approximate range of distance downstream of Merwin the naïve fish were captured/released for comparison with other two groups	Naïve fish were captured through the lower river generally from Lewis River Hatchery upstream to Merwin Dam boat barrier.
Josh Ashline NMFS	14	Page 5 Line 586	These are measurements of force not weight. I don't understand why you're not just reporting the tag weight in air and water. Also is there a minimum size fish you will tag based upon the size of the tag?	Weight is a force measurement of the effects of mass in a gravitational field. The mass does not change underwater, but the force does. Fish less than 18 inchs were not tagged.
Josh Ashline NMFS	15	Page 7 Line 631	Report the frequency in which the radio recievers were downloaded. Weekly? Daily?	Added clarifying content. Recievers were downloaded weekly.
Kale Bently WDFW	16	Page 11 Figure 4	Not a huge deal but APR was not intuitive to me. Had to look up in table above.	Noted.
Josh Ashline NMFS	17	Page 14 Line 721	M is not in Equation 3 Change to C	Changed
Kale Bently WDFW	18	Page 14 Line 721	C?	Changed to C
Kale Bently WDFW	19	Page 14 Line 724-5	So the "estimates" shown in the executive summary are not the actual (Bayesian) derived estimates? If this is true, why?	Regulatory agency currently does not care for estimation beyond the raw (ML) estimator.

Comment Matrix: Adult Trap Efficiency (ATE) Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee October 28, 2019.

Commenter	Comment Number	Location	Comment	Response
Kale Bently WDFW	20	Page 14 Line 732-4	Can you provide a bit more information as to how this was done? Did you use something like for non-naïve fish: Alpha = 2018 mean ATEtest * 2018 M (i.e., 0.7 * 63) Beta = (1-mean)*M (1 – 0.7 *63) In the results for Objective 8, you state that you used a mixture prior. Was that not used here? Why or why not? Did that look something like this? Alpha = (0.7*63)*0.5 + 1*0.5 Beta = (0.3*63)*0.5 + 1*0.5	As updating with equal weighting is equivalent to combining in Bayesian inference, 2018 data were combined with 2019. Alternatively, taking 2018 posterior mean and varience, then solved for alpha and beta, to provide ESS, using the following code: prior.a <- (((((1 - mn) / vr)) - (1 / mn)) * (mn ^ 2)) #calculates alpha parameter from mean and variance input above prior.b <- (prior.a * ((1 / mn) - 1)) #calculates beta parameter from mean entered above and alpha calculated above Mixture prior was used for total group because that comprises naïve and non-naïve fish, for which there were reasonable informative priors, and non-naïvePF fish, which were better served using a flat prior.
Kale Bently WDFW	21	Page 14 Line 734-8	Good to include this information. While I agree with your statement here, I would imagine that the choice of prior would have some influence on at least the credible intervals. Just worth acknowledging given that the performance metric is 98% and going to be hard to get a large “chunk” of the posterior distribution >=98% (which is a summary metric you are reporting) without larger samples (costly) and/or more informative priors	It does. Does not change conclusions though.
Kale Bently WDFW	22	Page 15 Line 771	I effectively skipped reviewing methods and results for objectives 2 - 7	Noted.
Kale Bently WDFW	23	Page 20 Line 915-6	I assume this means at any of the antenna sites throughout the Lewis River but not certain. Could re-word slightly to be more explicit.	Added clarifying content regarding radio telemetry recievers.
Josh Ashline NMFS	24	Page 20 Line 923	Is this technically entering the tailrace? I may have missed the definition of “tailrace”. If tailrace is not defined earlier in the document you should consider doing so.	Yes. Added clarifying content regarding defination.

Comment Matrix: Adult Trap Efficiency (ATE) Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee October 28, 2019.

Commenter	Comment Number	Location	Comment	Response
Kale Bently WDFW	25	Page 20 Line 926	Are you assuming 100% detection at all of your sites or at least the combination of sites within the trap lead to 100% detection? Have you explored some sort of "multi-state" model to estimate detection efficiency? Regardless of the answers to the above questions, it is worth mentioning something about detection efficiency (whether directly measured or just inferred) and how it may (or likely doesn't) affect the derived trap efficiency estimates.	Not assuming, rather presuming based on evaluating detection efficiency and comparing record of captured fish with detection history for trap receivers. Have not explored multi-state modeling approach, but that would be an acceptable idea as well.
Kale Bently WDFW	26	Page 20 Line 927	Do you have an idea of what detection efficiency is for this site? Basically, if they entered pool 2 (past the fykes) are you confident that all of the fish were detected at this point?	Efficiency is low at the Entrance. If they entered pool 2, they passed, but may have not been detected at, this site.
Kale Bently WDFW	27	Page 20 Line 928-9	Doesn't this suggest that PBB could be higher than estimated here given that detection efficiency isn't 100%?	PEE? If so, then yes, it would, except we computed PEE based on a detection at ENT or anything further upstream.
Kale Bently WDFW	28	Page 20 Line 929	Curious, if you knew detection efficiency at each location within the trap, couldn't you better pinpoint where fish are "escaping" and at what point fish are "stuck" and get back out at a much lower rate?	Detection efficiency would help to resolve where, precisely, in the trap, fish can escape from. Practically speaking, this would be very difficult to do given to small area of the ladder.
Josh Ashline NMFS	29	Page 20 Line 930-2	Just a methods suggestion….A second receiver cycling frequencies in a different order could assist in picking up more fish at the entrance. Also a pass over PIT array could be beneficial, as I'm sure these fish enter the entrance close to the bottom of the structure.	Noted. However, only one radio telemetry frequency was used during this study, so no cycling was needed.
Josh Ashline NMFS	30	Page 21 Figure 6	Thank you for doing this!	You are welcome! We made this change from your comments on the 2018 report.
Kale Bently WDFW	31	Page 22 Table 3	I'm a bit confused as to why the "raw" calculations are being reported as the estimates when you actually estimated all three of these "core metrics" using a Bayesian approach that accounted for the underlying generative structure/process of the data?	This a situation of regulatory targets versus, operational and infrastructural inference for making meaningful modifcation for improving passage.
Kale Bently WDFW	32	Page 23 Line 971	This is really just ATEtest, right?	Yes.
Kale Bently WDFW	33	Page 23 Line 975	Mean, median? Based on figure 9, I'm guessing these are means. Assuming these data are skewed, median probably more appropriate.	Yes, we reported mean here, but provided median in Figure 9. Added clarification to the text here.

Comment Matrix: Adult Trap Efficiency (ATE) Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee October 28, 2019.

Commenter	Comment Number	Location	Comment	Response
Josh Ashline NMFS	34	Page 24 Line 996	To me table 4 and Figure 7 are redundant. Table 4 provides more information and it is easy to see that the raw ATE test decreases later in the study period.	Noted. Some folks are more visual, so we included the figure for those folks.
Kale Bently WDFW	35	Page 26 Figure 8	Are these data points jittered? How can you have a recapture probability >1 or <0?	Yes, jittered. Added clarification in the text here.
Josh Ashline NMFS	36	Page 26 Figure 8	I feel that another statistical analysis (GLMM?) could be run using environmental factors such as daily discharge, and muscle lipid content. To identify if other co variates help/better explain the probability of recapture.	Yes, this has been discussed as potential future analysis.
Kale Bently WDFW	37	Page 27 Figure 9	This is a sweet plot. Looks like plots I've seen from John Kruschke blog and book. Were these generated using the "BayesianFirstAid" package you mentioned above?	Thanks for the kudos. No credit due to authors here, you are correc these are from the BayesianFirstAid package. Apologies if that wasn't clear and we gave the impression of inappropriately omitting a citation where it is due. Added citation.
Josh Ashline NMFS	38	Page 28 Line 1048	Why is data not presented for naïve and non-naivepf fish in the same structure? No heatmaps or network diagrams.	Core message regards naïve fish. Trying to avoid diluting the message with extraneous information
Josh Ashline NMFS	39	Page 31 Figure 11	I love this figure. It tells a great story. My only suggestion is to change the color scale to 10 different colors, for ease in telling probabilities apart.	Agreed. Color palette (viridis) was chosen to provide good contrast and be interpretable over a range of common color vision deficiencies (CVDs)
Josh Ashline NMFS	41	Page 39 Figure 15	Can you further define what you mean by this? Total number of detections at that site for all fish?	Yes. Added clarifying content to text.
Josh Ashline NMFS	42	Page 40 Figure 16	Why is there so much time spent in the hopper for Non-Naivepf fish? This should be low for all groups. Something odd is going on here.	This is real, due to three fish with very high residence time at this site.
Josh Ashline NMFS	43	Page 44 Line 1278	168 hours (7 days; Table 7)	Added clarifying content to text.
Josh Ashline NMFS	44	Page 45 Figure 19	I don't understand the switch in units here. Everything prior to this is reported in hours and you switch to minutes for the figure and Wilcox test.	Minutes provides greater resolution and ease of interpretation. Regulator metric is in hours.

Comment Matrix: Adult Trap Efficiency (ATE) Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee October 28, 2019.

Commenter	Comment Number	Location	Comment	Response
Josh Ashline NMFS	45	Page 55 Line 1499	As I said previously I appreciate the inclusion of the HBSC but have serious reservations. I agree that any unscheduled trap outage should be reported in the ATE reports, but outages should not be reported to inflate or deflate trap ATE measurements by presenting results of unaffected fish. The ATE is a measurement of how well the fish passage system is operating, and when it is not operating it is not passing fish. Thus the ATE for this time is 0%. Additionally while the trap is not operational fish that are migrating are prevented from doing so and must go into a holding or exploratory behavior which burns critical energy reserves (the importance of which is presented in this report) and shortens spawning windows. In the event that this report presented results of a ATE of 98% when correcting for unaffected fish, NMFS wouldn't accept these results, and I doubt the ACC would either.	Added content to Methods section (lines 895-989) to clarify intent here.
Kale Bently WDFW	46	Page 56 Line 1536-7	Why did you use a mixture model here but not in the original (unedited) dataset in Objective 1?	Mixture model here was to reflect that this group comprised subgroups for which we had reason to use informative priors (naïve and non-naïve) and a group for which we did not have reliable prior information (non-naïvePF). Added clarifying content to text here.
Kale Bently WDFW	47	Page 61 Line 1645	Interesting thought though I'm wondering how the handling of Naïve vs. non-naïve fish is different? Both are captured, measured, tagged, and then released. The major difference being the transport, right?	Yes, and as a result the total handling time (cumulative stress experience). Quite a different scenario between captured in river, worked up on a boat, then released almost immediately, and captured at dam after attempting (potentially many times) to pass, being elevatored up to a holding tank, head for some time, crowded, worked up, held, loaded into a truck, transported downstream, and then released.
Kale Bently WDFW	48	Page 61 Line 1651-2	What exactly does this mean? The ATEtest 95% credible did not overlap the 98% performance standard?	Yes.
Kale Bently WDFW	49	Page 61 Line 1664	Changed wording slightly because the estimated ATEtest for naïve fish in 2019 was technically less than the 98% performance standard – a larger sample size does not guarantee that ATEtest ≥ ATEtarget	Change accepted.

Comment Matrix: Adult Trap Efficiency (ATE) Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee October 28, 2019.

Commenter	Comment Number	Location	Comment	Response
Kale Bently WDFW	50	Page 62 Line 1684	This contradicts the following sentence. Do you mean Non-NaïvePF?	Yes, should have read Non-NaïvePF. Text changed to reflect correction.
Kale Bently WDFW	51	Page 62 Line 1697	Seems like this would be a good metric to more formally track.	Noted. Will consider for future analysis.
Kale Bently WDFW	52	Page 62 Line 1698-1703	But didn't you hypothesize earlier that lower flows leads to higher trap entrance? Is there a way to achieve both?	Yes. Increasing fyke effectiveness, constructing a second fyke, or making the existing fyke opening smaller or more acutely angled are are possibilites.
Josh Ashline NMFS	53	Page 64 Line 1737-47	The trap is not inclusive of the diversity of fish returning to Merwin Dam and upstream to spawn. This should be addressed. Currently its selecting for larger fish with more lipid content, or the earlier run of fish. Passage at Merwin should be inclusive of the diversity of fish returning throughout the run.	Disagree. Fish in very poor condition including spawed out fall Chinook and coho salmon have been collected in the Merwin Trap. It has also captured a number of Tigar Musky spilled from Merwin Reservior as well as salmon smolts. The general thought here is that fish will low lipid content don't attempt to pass Merwin Trap, because they are done and want to spawn. Remember, most of these fish were non-naive and had aleardy passed once.
Josh Ashline NMFS	54	Page 64 Line 1756	Please expand on this statement. It reads that fish were trapped in the trap for 5 days. Which I really hope didn't happen.	Added clarifying content to text.
Kale Bently WDFW	55	Page 65 Line 1798-1801	Not a huge deal but I would break this sentence apart. It is a little hard to follow as you are trying to compare several metrics and all three groups simultaneously.	Change accepted.

Comment Matrix: Adult Trap Efficiency (ATE) Evaluation - Final 2019 Report reviewed by the Lewis River Aquatics Corrdination Committee October 28, 2019.

Commenter	Comment Number	Location	Comment	Response
Kale Bently WDFW	56	Page 65 Line 1806-7	I don't quite understand the conclusion here. Makes sense that Non-Naïve may have fewer directed movements and longer residence times in the tailrace compared to fish released further downstream but why would this affect their ability to ultimately enter the trap (Pbb) and be retained (ATE)? This would make some sense if you have an uneven proportion of tagged fish (N) "falling out" before entering the tailrace (M) – either due to stress/injury or trap avoidance - but this proportion (95%) is identical across all three groups: -Non-NaïvePF: 41/43 -Non-Naïve: 39/41 -Naïve: 22/23 I could be missing something but maybe worth providing a bit more explanation (if it can be explained).	We interpreted the findings that non-naïve fish exhibited less direct moveemnts than non-naïvePF fish as one of the primary pieces of evidence suggesting that non-naive fish have not yet fully recovered from the stress of handling, and are in a compromised physiological state. Support was provided by the observation that the non-naive fish entered the trap at lower rates than non-naivePF fish, supporting some aversive operant conditioning may also be at work. The observation that the non-naive fish were trapped at higher rates than non-naivePF fish is difficult to explain.
Kale Bently WDFW	57	Page 66 Line 1815	What do you mean? Why is there low confidence? You just said in the previous sentence that Naïve fish should be the preferred group to evaluate ATE. Do you mean estimates are less precise due to low(er) sample sizes?	Yes, less statistical confidence due to low sample sizes. Added clarification to the text here.

MERWIN UPSTREAM PASSAGE ADULT TRAP EFFICIENCY – WINTER STEELHEAD

2019 Final Annual Report

Prepared for:

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27 February 2020

EXECUTIVE SUMMARY

This report describes results from the fifth 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 winter 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 proportional difference between P_{EE} and ATE_{test}. Evaluation of T_i can reveal an operational or infrastructural bottleneck 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 primary objectives of the 2019 Merwin *ATE* evaluation were as follows:

1) Determine ATE_{test} 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, 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 from a release point approximately 0.5 km (0.3 mi) downstream of the dam and trap. It was proposed that estimates of core passage metrics could be biased if fish were less likely (or less inclined) to locate and enter the Merwin Dam fish trap a second time.

Beginning in 2018 and continuing in 2019, core passage metrics and movements were evaluated for two release groups of fish:

- Trap Non-Naïve: Fish captured and tagged at the Merwin Fish Collection Facility, then subsequently released immediately (approximately 0.5 km) downstream of Merwin Dam; and
- Trap Naïve: Fish captured, tagged and released downstream from Merwin Dam, and thus presumably with no prior encounter with the trap.

In addition to the two release groups described above, a third release group was included in 2019:

- Trap Non-Naïve$_{PF}$ Fish captured and tagged at the Merwin Fish Collection Facility, then subsequently released approximately 29 km downstream of Merwin Dam at S. Pekin Rd. boat launch near the mouth of the Lewis River. These fish were identical to the Trap Non-Naïve group except that they were released further downstream.

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

Core passage metrics from 2015-19 are summarized in Table 1, below.

Table 1. Values for P_{EE}, ATE_{test}, and T_i across study years. 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 and 2019 used Bayesian Credible Intervals, whereas all other study years used bias-corrected and accelerated methods. In addition, P_{EE} and ATE_{test} credibility intervals in 2019 were estimated using priors based on 2018 results for the Naïve and Non-Naïve release groups.

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%
	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%
2019	winter steelhead	107	94% (88-97%)	84% (76-90%)	10%
	Non-Naïve	41	87% (88-97%)	85% (81-93%)	3%
	Naïve	23	100% (91-100%)	95% (87-99%)	5%
	Non-Naïve$_{PF}$	43	98% (81-97%)	78% (63-88%)	20%

Key results from the 2019 study pertaining to the core passage metrics for winter steelhead include the following:

- 107 BWT winter steelhead were tagged between February 25^{th} and May 1^{st}
- 104 adults were detected in the study array somewhere in the North Fork Lewis River
- 102 adults entered the tailrace of Merwin Dam following release (*M*)
    - *These individuals compose the group of fish that were included in estimates of core metrics per Objective 10 of the Lewis River Monitoring and Evaluation Plan (PacifiCorp and Cowlitz PUD 2016).*
- 96 steelhead entered the trap (*T*)
    - Combined P_{EE} = 94% (96/102)
    - P_{EE} for Non-Naïve fish = 87% (34/39)
    - P_{EE} for Naïve fish = 100% (22/22)
    - P_{EE} for Non-Naïve$_{PF}$ fish = 98% (40/41)
- 86 steelhead were successfully recaptured (*C*)
    - Combined ATE_{test} = 84% (86/102)
    - ATE_{test} for Non-Naïve fish in 2019 = 85% (33/39)
    - ATE_{test} for Naïve fish in 2019 = 95% (21/22)
        - 95% credible intervals for ATE_{test} for Naïve fish in 2019 includes the 98% *ATE* performance standard
        - There was an 18% posterior probability that the true *ATE* of the Naïve fish parent population met or exceeded the target
        - ATE_{test} for Naïve fish in 2019 (95%) and 2018 (100%) were highest ATE_{test} values reported across all study years and species evaluated at Merwin Dam
    - ATE_{test} for Non-Naïve$_{PF}$ fish in 2019 = 78% (32/41)
    - Among the release groups, ATE_{test} was greatest for naïve fish, although significance of group differences ranged from highly significant (Naïve>Non-Naive$_{PF}$) to marginally significant (Naïve>Non-Naïve).

We also compared the amount of time that fish were present in the tailrace to performance standards. Median tailrace residence time was 22.6 hours, which is below (i.e., achieves) the performance standard of median tailrace residence time less than 24 hours. However, 7% of fish exhibited tailrace residence times greater than 168 hours, which is above the maximum (i.e., does not achieve) the performance standard of less than 5% of fish residing within the tailrace for this long. Notably, both these performance standards for tailrace residence time were met for Naïve fish, whereas both were not met for Non-Naïve fish in 2019 (only the former was met for Non-Naïve$_{PF}$ fish). Unscheduled trap outages that occurred in 2019 appear to have inflated tailrace residence times.

Consistent with previous years, during the 2019 study year the combined group of tagged winter steelhead appeared to locate and enter the trap at a higher rate (P_{EE} = 94%) than the rate at which they were captured (ATE_{test} = 84%). This observation is reflected by a trap ineffectiveness (T_i) of 10% for 2019, which is similar to the ranges reported for T_i in years following installation of a fyke inside the trap in 2017-18 (0-10%), and lower than T_i before installation of the trap in 2015-16 (18-21%). Thus, based on three years of study since installation, the fyke appears to be effective for reducing the number of fish that leave the trap without being trapped.

Despite the fyke being effective in reducing T_i, 63% of steelhead that entered the trap during the 2019 study season later exited the trap. Most of these were eventually recaptured, hence T_i was only 10%. The proportion of fish that exited in 2019 (63%) was greater than the proportion of fish that exited the trap in 2018 (50%) and more than twice the proportion of fish that exited the trap in 2017 (approximately 20%), 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 2019, the performance standard of 98% *ATE* would have been achieved for two out of the three release groups.

In general, steelhead appeared to be highly attracted to the tailrace and trap during the 2019 study season. Evidence in support of this includes the following observations:

- The proportion of study fish reaching the tailrace was high (approximately 95%).
- Winter steelhead generally exhibited high transition rates moving upstream towards the tailrace and trap from downstream locations.
- Few (n = 4) steelhead were detected in neighboring tributaries suspected of attracting strays.
- Non-Naïve$_{PF}$ returned to the tailrace and trap at high rates, despite being released approximately 29 km downstream from Merwin Dam.
- Once steelhead entered the tailrace in 2019, the path most frequently used was along the south side of the tailrace where the trap entrance is located.
- 94% of fish that entered the tailrace located the trap entrance (i.e., P_{EE}).
- P_{EE} was high for all release groups (range = 87-100%).

High attraction to the tailrace and trap could be related to 2019 flows within the Lewis River, which were the lowest among study years. We hypothesize that olfactory cues provided by hatchery effluent that is routed through the trap entrance into the Lewis River as part of attraction flows are diluted when Lewis River flow is high and concentrated when Lewis River flow is low. Higher concentrations of olfactory cues provide better navigational cues to homing hatchery-origin (HOR) steelhead. This, in turn, increases their ability to locate the tailrace and trap from locations downstream. Additional analysis would be needed to resolve these relationships.

Results from the 2019 study also indicated that, compared to Naïve and Non-Naïve$_{PF}$ fish, Non-Naïve fish:

- Non-naïve fish exhibited more milling behavior in the tailrace than either Naïve or Non-Naïve$_{PF}$ fish.
- Non-naïve fish visited twice as many radio telemetry receiver sites on average, compared to either Naïve or Non-Naïve$_{PF}$ fish. This was in spite of Non-Naïve$_{PF}$ fish being released approximately 28 km *further downstream* from Merwin Dam compared to Non-Naïve fish.
- Non-naïve fish spent 40 more hours in the tailrace on average, compared to either Naïve or Non-Naïve$_{PF}$ fish.
- Non-naïve fish used the most stored somatic energy after release of any group.

a. Non-naïve and Non-Naïve$_{PF}$ fish used significantly more (17.5 and 15 fold more, respectively) energy than Naïve fish, based on measurements of muscle lipid content taken before release and after re-capture at Merwin Dam.
b. Non-Naïve and Non-Naïve$_{PF}$ fish used similar amounts of energy following release, again, despite Non-Naïve$_{PF}$ fish having to swim upstream an additional approximately 28 km to reach Merwin Dam.

Evidence from two years of study comparing Naïve and Non-Naïve fish indicate Non-Naïve fish exhibit less directed movements toward the trap compared to Naïve fish. We hypothesize that Non-Naïve fish, which are released relatively close (approximately 0.5 km) to the Merwin Dam, have not had the chance to recover from stress induced during trapping and handling. Moreover, Non-Naïve$_{PF}$ fish, which are subjected to identical trapping and handling as Non-Naïve fish (except being released further downstream), also showed more directed migration compared to Non-Naïve fish and similar behaviors as Naïve fish. The more directed migration of Non-Naïve$_{PF}$ fish suggests they had recovered from handling stress by the time they enter the tailrace. This provides additional support for our hypothesis that Non-Naïve fish behavior in the tailrace is influenced by stress because of their close release location to the tailrace.

Overall, Naïve steelhead have outperformed Non-Naïve fish in both study years, and ATE_{test} for Naïve fish in 2018 (100%) and 2019 (95%) was the highest across all study years thus far. Despite high ATE for Naïve fish, there was still a low statistical probability (18%) that Naïve fish met or exceeded the 98% performance standard for passage efficiency at Merwin Dam, reflecting uncertainty deriving from the modest sample size for this group. We suggest that Naïve fish are the most appropriate release group for evaluating performance standards at Merwin Dam because they are the most representative of the parent population of steelhead in the Lewis River. We also suggest that, whenever possible, future studies examining performance standards of migrating salmonids at fish passage structures utilize fish that are naïve to the fish passage structure and are captured further downstream to allow for recovery before fish interact with the passage structure.

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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).

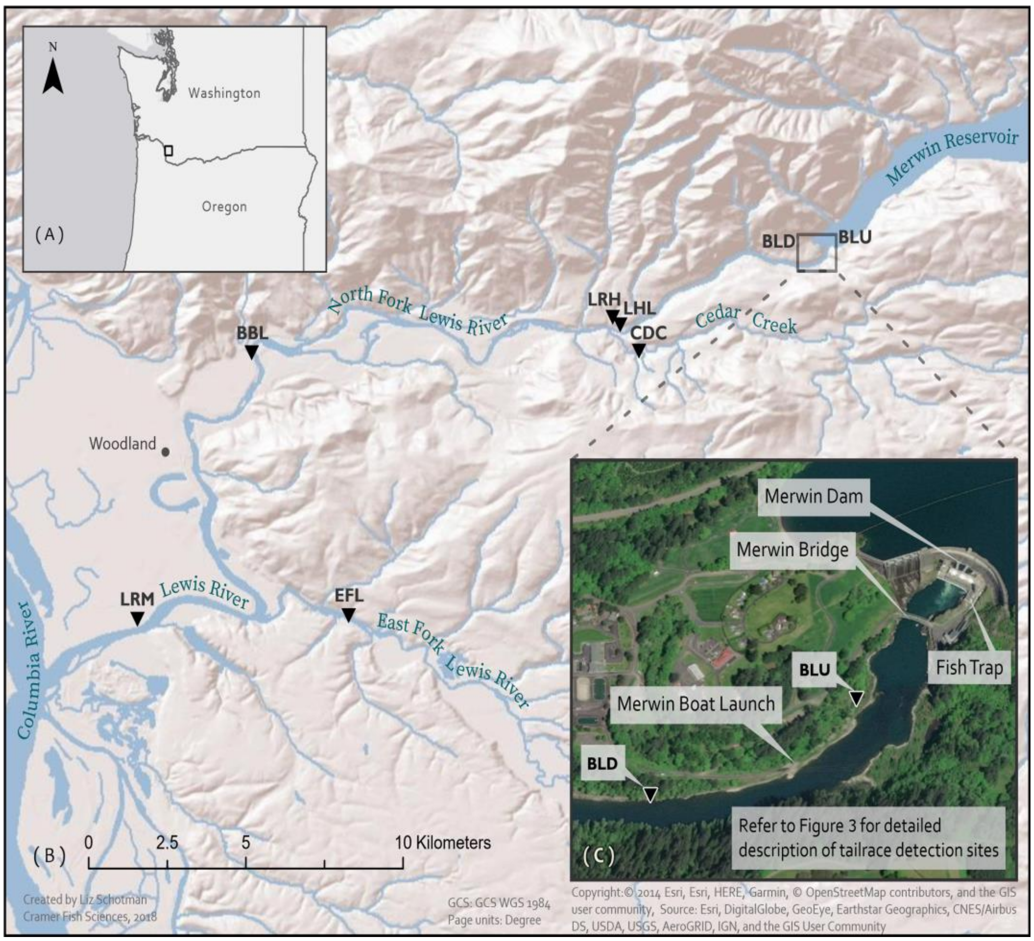

Figure 1. Project area map indicating study region (A), extent of study within the Lewis River system (B), and study area and infrastructure near Merwin Dam (C). Black triangles indicate radio detection sites.

[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 coauthors 2004)*].

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 passage metrics for 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, 2019). Consequently, over the course of the study years, dam infrastructural and trap and dam operational adaptations have been undertaken to improve *ATE*. These efforts have also improved our 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 the 2017 study season, 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).

In addition, 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 when flow was high (greater than 8,000 cfs) within the NF Lewis River (Drenner et al. 2018a). Additional data collected in 2018 provided further evidence that flow influences *ATE* at Merwin Dam, suggesting low flow within the NF Lewis River could be associated with increased attraction to the tailrace and therefore, improved passage efficiency (Drenner et al. 2018c, 2019). 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. In contrast, in 2018, 12% of coho salmon were detected in tributaries and 21% of coho returned to the Lewis River Hatchery, which is downstream from the Merwin Dam tailrace. The observation that many coho returned to the Lewis River Hatchery may not be surprising given that 90% of coho salmon included in the 2018 study were hatchery origin (HOR) fish from the Lewis River Hatchery.

To evaluate the influence of fish biological condition on *ATE*, in 2018, fish muscle lipid content—a proxy for overall fish condition—was estimated for individual winter steelhead and coho salmon 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 (Drenner et al. 2018c), but there was no relationship between muscle lipid content and re-capture rates for coho salmon (Drenner et al. 2019). Overall these results suggest that background physiological condition of fish influences their probability of re-capture.

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. Importantly, this means that these fish must locate and enter the trap a second time, following release. The use of previously trapped fish or fish that successfully ascended a dam fishway is common in fish passage studies, for two reasons. First, it increases the likelihood that fish are volitionally targeting upstream spawning habitat. Second, capturing fish that are confined in a trap or narrow fishway is logistically easier than capturing fish that are swimming freely in a large river. However, one explicit assumption of Cramer Fish Sciences' (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. We suspected that this method of capturing fish at Merwin dam, then presenting them with a second passage challenge may lead to negatively biased estimates of fish passage success. Consequently, we hypothesized that re-capture probability would differ among groups of fish that were initially captured above the dam (after a successful passage attempt) versus below the dam (prior to any passage attempt).

To test this 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—likely related to low sample sizes for Naïve fish—the results did indicate an 80% probability that Naïve fish had higher *ATE* compared to Non-Naïve fish. Furthermore, Naïve fish spent less time in the tailrace, visited fewer sites, and exhibited more direct movements overall compared to Non-Naïve fish. These results provided evidence for biological and potentially meaningful differences between trap Naïve and trap Non-Naïve fish, but additional data was recommended to further evaluate differences.

Study Objectives

The primary goal of this fifth 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 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.

The specific objectives for the 2019 steelhead evaluation included the following:

1) Determine *ATE* for steelhead at Merwin Dam and compare estimates to the performance standard of 98%.
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*.

During 2019 steelhead *ATE* monitoring, the trap experienced an unscheduled outage and the fyke inside the trap had to be repaired, either of which could have resulted in lower *ATE*. To evaluate the effects of the unscheduled trap outage and fyke repair, an eighth objective was introduced to the 2019 steelhead *ATE* report:

8) Evaluate the effects of unscheduled trap outages on core metrics and performance standards for the purposes of a hypothetical analysis to guide PacifiCorp in evaluating potential operational or infrastructural changes to improve fish passage at the Merwin trap.

METHODS

Fish Collecting and Tagging

All fish included in this study were blank wire tagged (BWT) hatchery winter steelhead (hereafter, 'steelhead') collected and radio tagged by PacifiCorp staff from late-February through early-May 2019 (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 approximately 0.6 km (0.4 mi) downstream of Merwin Dam at the Merwin Boat Launch (Figure 1). This group is analogous to fish used to estimate core metrics in the first three study years, and thus allows interannual comparisons of core metrics across the study years.
- Trap **Naïve** release group – fish were captured by angling, tagged and released in the NF Lewis River. *One explicit assumption of this study is that none of the fish included in this 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$_{PF}$** release group – similar to the Non-Naïve release group, fish in this release group were captured and tagged at the Merwin Dam Adult Fish Collection Facility. However, instead of being released at the Merwin Boat Launch, this group was transported and released at Pekin Ferry approximately 29 km downstream from Merwin Dam near the Lewis River mouth. Trap Non-Naïve$_{PF}$ fish were released further downstream to test whether release location is associated with trapping rates and behavior following release. We hypothesized that behaviors observed by fish released closer to the dam (as was the case for Non-Naïve fish) may be influenced by stress from capture, handling, and transport. Thus, these observations may reflect influences associated with recovery, rather than baseline behaviors. We presume that Non-Naïve$_{PF}$ fish have recovered by the time they reach upstream areas of the NF Lewis River and, therefore, are more comparable to Naïve fish, which are also released further downstream.

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 and release location, individual fish condition was quantitively assessed using two methods prior to release. 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 was estimated for each fish, using handheld microwave sensors (Distell Fatmeters, https://www.distell.com/), following protocols presented in Caldwell et al. (2013) (Figure 2). A subset of fish that were re-captured at the Merwin Dam Fish Collection Facility were measured for energetic reserves a second time to understand energy use based on difference in muscle lipid conent.

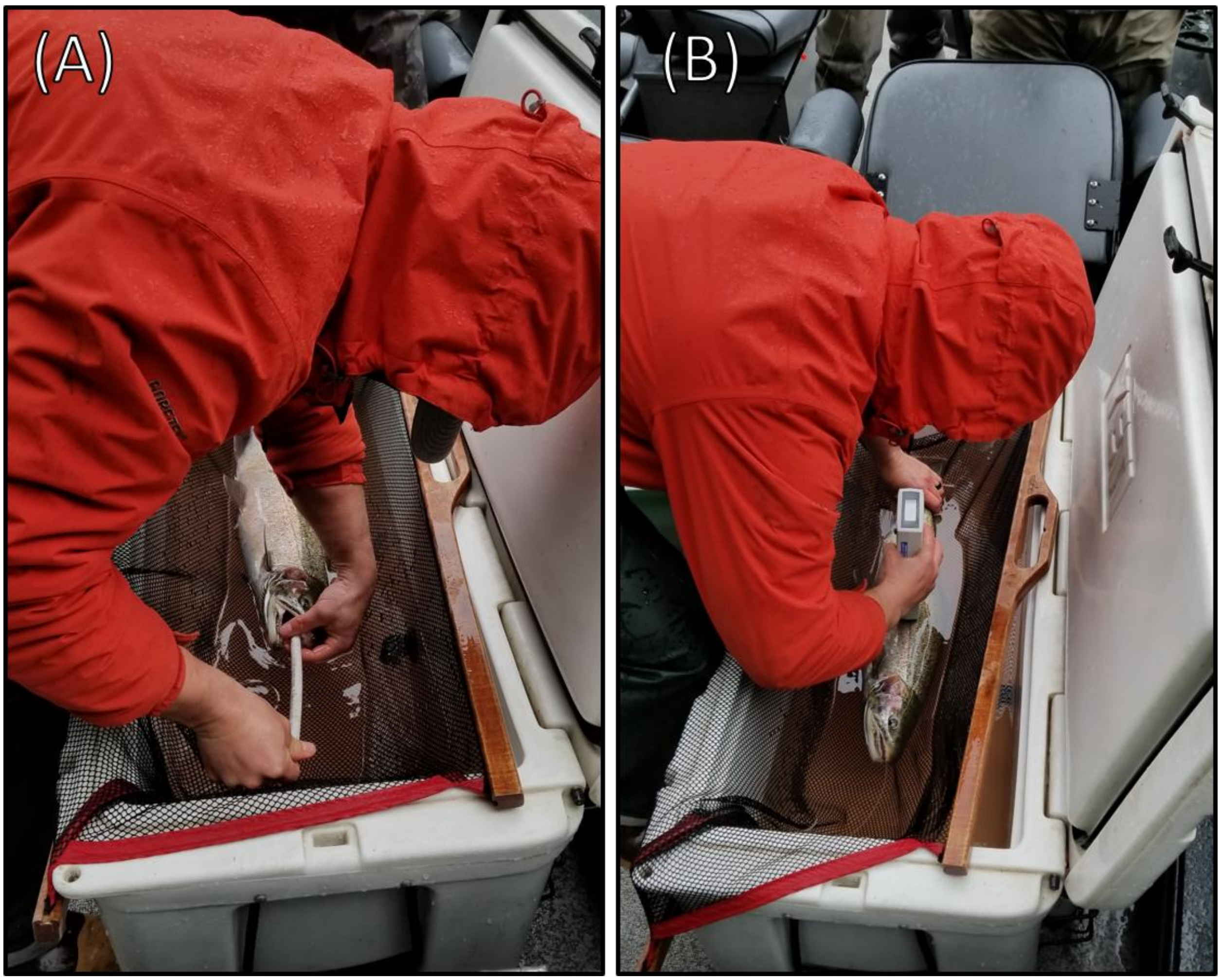

Figure 2. Photos taken during winter steelhead tagging procedure at a tangle netting site (Drenner et al. 2018c), similar to methods described herein. Photos show radio tag being inserted gastrically (A) and Fatmeter being used to measure muscle lipid content (B). Photos courtesy of PacifiCorp.

All fish were allowed to recover following the tagging procedure. Fish tagged at angling sites downstream were released overboard immediately after the tagging procedure. Fish tagged at the Merwin Fish Collection Facility were transferred to a water tank on the back of a truck and transported to the release site at the Merwin Boat Launch or Pekin Ferry. A maximum of 11 fish were tagged and released on any given day to reduce the frequency of tag collisions at receivers within the array.

Fish Tracking

Following release, movements of tagged fish were monitored using an array consisting of 19 fixed radio telemetry 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 included a radio receiver (Lotek 19 SRX800D). Receivers had the ability to store approximately 1 million detection records each, between datalogger downloads. Receivers were downloaded weekly.

Detection site locations in 2019 were identical to those used in 2018 with these exceptions:

- The Lewis Hatchery Ladder (LHL) site was re-located from the ladder leading into the Lewis River Hatchery to the holding pond inside the hatchery. The new site location is intended to detect tagged fish that entered the hatchery holding pond, thereby providing confirmation of tagged fish captured at 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

[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
	LHL	Lewis Hatchery Ladder	Underwater dipole antenna located within the holding pond inside the Lewis River Hatchery	Confirm fish recaptured at the 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 the confluence with the Columbia River	Confirm fish in the study area and potential of fish exiting the Lewis River	142.5

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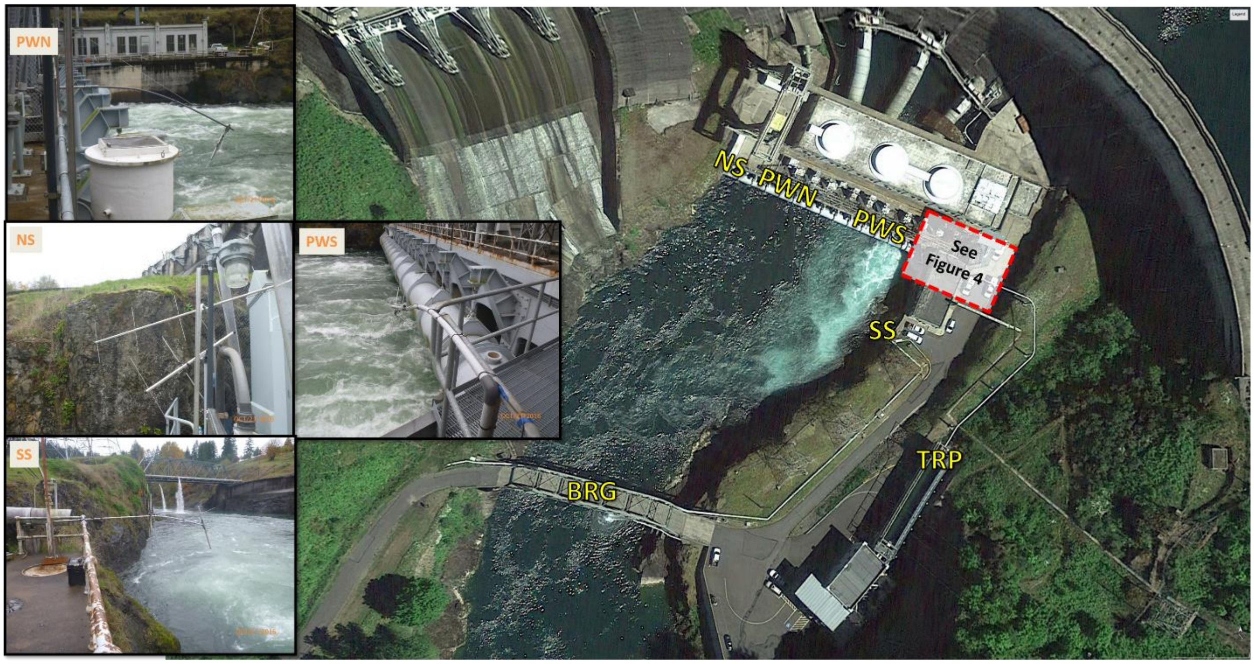

Figure 3. Merwin Dam tailrace area with locations of stationed antennas and pictures of select antenna orientations. All antennas listed in this figure are aerial, except for the Trap. Details of antennas deployed within the trap are shown on the trap schematic in Figure 4. Aerial image taken from Google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

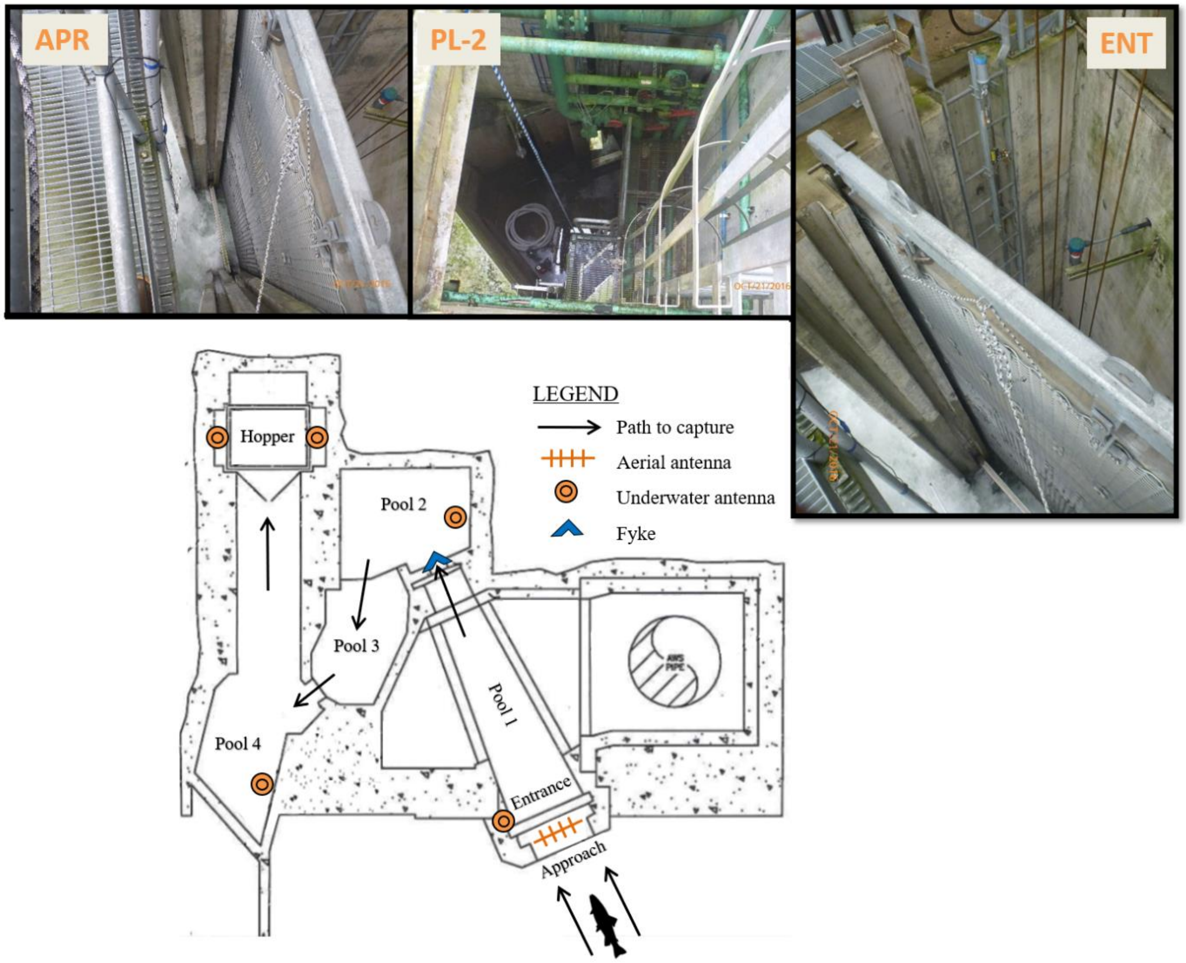

Figure 4. Trap schematic showing the locations of antenna arrays, with arrows showing the progressive movements fish make to reach the hopper and pictures of select antenna orientations. Photos provided by Cramer Fish Sciences.

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 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 post-processed (filtered) to remove noise and tag codes not included in the study. Filtered data were then compiled into a Microsoft Access database, before a second filtering process developed by Stevens et al. (2015) was applied to the data. This second 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 filtering, 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. *ATE* is one of two metrics that have been developed in order to evaluate trap efficacy (the other being P_{EE}; see below). Observations of *ATE* among samples of study fish are essentially data points that are used to estimate *ATE* for the parent population and test whether these local populations meet ATE_{target}. Consequently, these estimates of *ATE* are referred to as ATE_{test}. ATE_{test} is calculated as the proportion of fish entering the Merwin Dam tailrace (*M*) that were ultimately captured at the trap (*C*):

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

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, and

C is the number of fish successfully captured, 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 a sample group, 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*). *T* includes fish detected at the trap entrance or any receivers upstream of the trap entrance. P_{EE} is then calculated as follows:

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

where:

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

M is 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 entered the trap but were not trapped:

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

where:

T is as defined for Equation 2, above, and

C is as defined for Equation 1, above.

As a point of clarification, greater T_i values correspond with lower trap effectiveness.

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$_{PF}$) as well as for all fish combined (‘Total’). Observations (raw estimates) are presented in tables for the purposes of reporting and data summary.

To generate informed estimates of metrics, and to statistically compare core metrics with targets, and compare 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 study years, data for the Naïve and Non-Naïve groups from 2018 were the only previous data determined to be appropriate for setting priors used in Bayesian inference of binomial proportions for those groups of fish in 2019. For evaluations of all fish combined, and for the Non-Niave$_{PF}$ group, we used a uniform Bayes-Laplace (beta (1, 1)) prior for all binomial proportion inferences. 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 qualitatively similar in terms of conclusions drawn.

The result of these efforts is a series of posteriors for each core metric for each group. Posteriors contain all of the information (i.e., prior assumptions and data) and provide the complete inference from the Bayesian perspective. This includes including statistical moments for central tendency (e.g., mean, median) and precision (e.g., variance) (Bolstad 2007). 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 developing 95% HDIs from the posterior estimates for the suite of metrics associated with each group. After generating a 95% HDI, testing a hypothesis regarding threshold targets (i.e., comparing ATE_{test} to ATE_{target}) at a 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 over which ATE_{test} is equal to or greater than ATE_{target} for each group, to arrive at the probability that the target passage rate was truly acheived.

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 were constructed to model response of binomial passage success as zero (not re-captured) or one (re-captured), based on date-time as the primary predictor variable, using a logit link function, i.e., logistic regression. Temporal trends were then examined separately for release groups.

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 (effect size) and the overall probability of difference (confidence) among groups. To facilitate this process, a Bayesian proportions test was used to compare ATE_{test} among release groups, using the Bolstad (Curran & Bolstad 2018) and BayesianFirstAid (Bååth 2014) packages within Program R (R Core Team 2018). All analyses were conducted with priors described above.

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 evaluate 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 by interpolating missing sites.
  - 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 these fish behaved through the tailrace and trap entrance zone. Linearizing the path to the Bridge receiver, and then forcing them to enter the trap through the Entrance receiver would create multiple false transitions since we do not know what happened in their approach to 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. As a result, comparisons among network diagrams are somewhat limited.

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*

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

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

To evaluate behavioral differences among release groups, comparisons were made based on the following:

- Wilcoxon rank sum test comparing median number of sites visited among release groups
- Transition rates and milling index of Naïve, Non-Naïve and Non-Naïve$_{PF}$ 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. 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, Non-Naïve and Non-Naïve$_{PF}$ fish. A non-parametric Wilcoxon rank sum test was used to test if median tailrace passage times for Naïve, Non-Naïve and Non-Naïve$_{PF}$ 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 among groups that enter and remain in the trap versus those that enter and then leave 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 conducted all trapping, tagging, and fish health assessments. 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 quantitative 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 release. Fish energetic state was evaluated for evidence of effects associated with the following: a) release date, b) release group, c) sex, and c) fate after release. The effect of release date was evaluated using linear regression. The effect of release group (Naïve, Non-Naïve, Non-Naive$_{PF}$) was evaluated using GLMs. The effects of sex and fate after release were evaluated using Wilcoxon rank sum tests.

Reflex impairment was assessed for individual fish following RAMP protocols (see Raby et al. 2012). The resulting RAMP scores represent the proportion of the five assessed reflexes that were impaired, meaning that RAMP scores closer to zero imply less reflex impairment, while scores closer to one imply greater impairment. Descriptive statistics for RAMP scores are presented below; 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.

NF Lewis River discharge (cfs) data were obtained from USGS (USGS 2019). Data for total NF Lewis River discharge are presented along with discharge data from previous study years to graphically evaluate the effects of discharge on passage success.

Objective 8: Evaluate the effects of unscheduled trap outages and fyke issue on ATE and T_i, respectively.

First, we describe the circumstances of the unscheduled trap outage and fyke repairs that occurred in 2019. We then summarize the number of fish affected by these events and compare core metrics and performance standards among fish that were affected and unaffected by these events. The purpose of this objective is to provide hypothetical results that could guide operational or infrastructural modifications by PacifiCorp to improve passage. We explicitly note that the purpose of this objective is *not* regulatory.

RESULTS

Summary

From 25 February – 01 May 2019, 107 adult BWT winter steelhead (51 females; 56 males, FL = 54 – 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 107 tagged steelhead, 41 were trap Non-Naïve fish, 23 were trap Naïve, and 43 were trap Non-Naïve$_{PF}$. Below, we present results summaries for these release groups. Numbers of detections among all receivers are visualized in Figure 6 and summarized along with instances of tag shed, tag failure and mortalities below. Summary data on individual fish and their detections are presented in Appendix A-3.

- Five fish either shed their radio tag or experienced tag failure but were later re-captured in the Merwin Dam fish trap and identified by PIT tags.
    - *Tag sheds are accounted for in the core metrics presented herein (e.g., fish re-captured without detections in the tailrace or trap were added to total counts of fish that entered the tailrace and were trapped).*
- 104 fish (97% of total) were detected at least once within the array of radio receivers deployed for this study (the "detection array").
- Three (3%) of the tagged fish were detected in the East Fork Lewis River and one (1%) of the tagged fish was detected in Cedar Creek. These two sites represented the sites with the fewest number of fish detected.
- Among the other sites with detections, small numbers of fish were detected at the Lewis River Mouth site (*n* = 25), the Bed & Breakfast site (*n* = 51), and the Lewis River Hatchery site (*n* = 51), while the most fish were detected at the Boat Launch Upstream site (*n* = 99).
- 102 fish (95% of total) entered the Merwin Dam tailrace (defined as at or upstream of the bridge receiver). One of these was detected at the Bridge site only, and never further into the tailrace.
- 96 fish (90% of total) entered the trap (i.e., were detected at the Entrance site or further upstream), all of which were detected past the fyke at the base of Pool 2.
    - Low numbers of fish detected at the Entrance site (*n* = 53) 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.

- 86 fish (80% of total) were re-captured at the Merwin Dam Adult Fish Collection Facility, comprising equal proportions of females (41/51) and males (45/56).

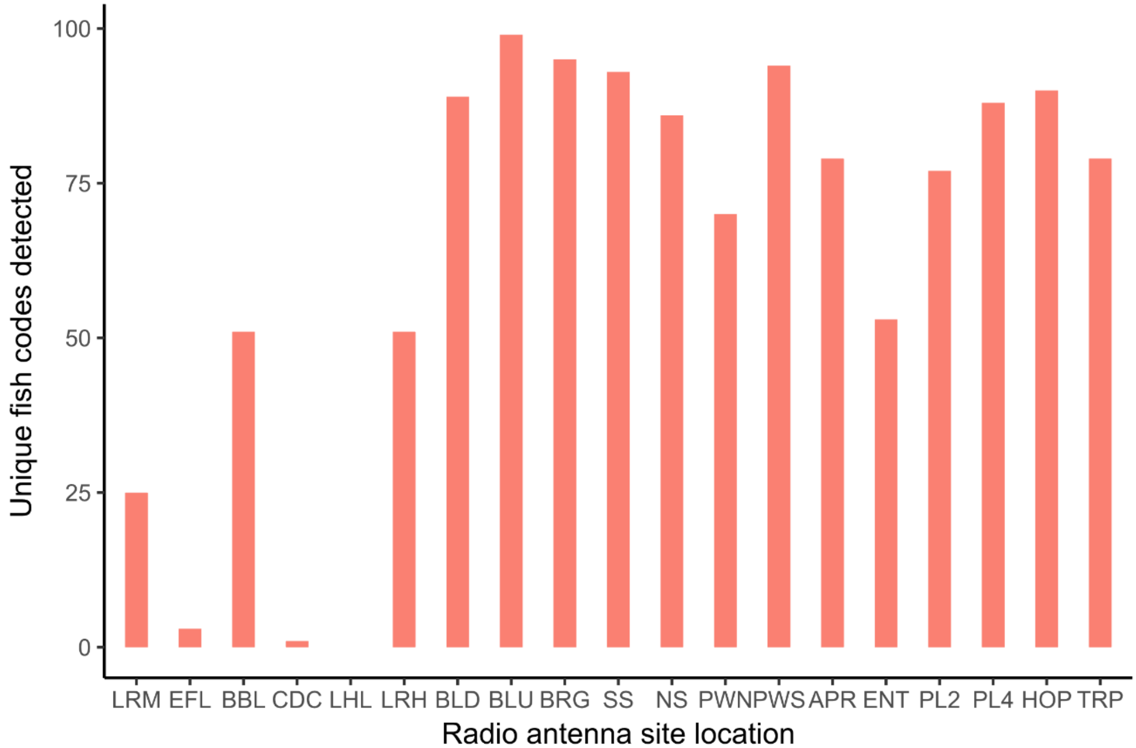

Figure 6. Numbers of unique fish codes (i.e., fish IDs) detected on each radio receiver site within the study area. See Figure 1, Figure 3, and Figure 4 for receiver locations. Abbreviations are given for sites as follows: LRM (Lewis River Mouth); EFL (East Fork Lewis); BBL (Bed & Breakfast); CDC (Cedar 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 and compare to performance standard (98%)

Objective 1a: Estimate core passage metrics

Total:

During the 2019 study season, 107 steelhead were tagged (*N*). Of these 107 fish, 102 were detected within the Merwin Dam tailrace (*M*), 96 were detected entering the Merwin Dam trap (*T*), and 86 were ultimately captured (*C*). These counts provide the basis for estimation of core metrics (Table 3):

- P_{EE} = 94% (96/102)
- ATE_{test} = 84% (86/102)
- T_i = 10% (10/96)

Table 3. Summary of passage metrics for tagged steelhead approaching the tailrace of Merwin Dam during spring/summer 2019.

Metric	Non-Naïve	Naïve	Non- Naïve$_{PF}$	Total
Tagged Fish (*N*)	41	23	43	107
Entered the Tailrace (*M*)	39	22	41	102
Entered the Trap (*T*)	34	22	40	96
Captured (*C*)	33	21	32	86
Raw Trap Entrance Efficiency ($P_{EE} = \frac{T}{M}$)	87%	100%	98%	94%
Raw Collection Efficiency ($ATE_{test} = \frac{C}{M}$)	85%	95%	78%	84%
Raw Trap Ineffectiveness ($T_i = \frac{T-C}{T}$)	3%	5%	20%	10%

Non-Naïve:

While 39 Non-Naïve fish entered the tailrace, five of these failed to enter the trap (raw P_{EE} = 87%). One of the Non-Naïve fish that entered the trap was not re-captured (raw ATE_{test} = 85%). P_{EE} for Non-Naïve fish was lowest among release groups, while ATE_{test} was intermediate, being lower than for Naïve fish and higher than for Non-Naïve fish.

Naïve:

All trap Naïve fish that entered the tailrace subsequently entered the trap (raw P_{EE} = 100%). However, one Naïve fish that entered the trap was not recaptured (raw ATE_{test} = 95%). Both raw P_{EE} and ATE_{test} metrics for Naïve fish were the highest among release groups.

Non-Naïve$_{PF}$:

A total of 41 Non-Naïve$_{PF}$ fish entered the tailrace, one of which failed to enter the trap (raw P_{EE} = 98%). Eight of the 40 Non-Naïve$_{PF}$ fish that entered the trap were never re-captured, resulting in the lowest raw ATE_{test} among release groups (78%) and highest T_i among release groups (20%).

Objective 1b: Evaluate core passage metrics against performance standards

Core passage metrics were evaluated against performance standards for all three groups as well as a 'Total' group.

Total:

The mean of the Bayesian posterior ATE_{test} estimate for the Total number of fish that reached the tailrace (n = 102) was 91% (95% HDI = 76-90%). There was a greater than 99.9999% posterior probability that the true *ATE* value of the parent population for this group was less than 98%. That is, there was a less than 0.0001% 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 = 39) was 88% (95% HDI = 81-93%). There was a 99.9% posterior probability that the true *ATE* value of the parent population for this group was less than 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 = 22) was 95% (95% HDI = 87 – 99%). There was an 82% posterior probability that the true *ATE* value of the parent population for this group was less than 98%. That is, there was an 18% posterior probability that the true *ATE* of the parent population met or exceeded the target.

Non-Naïve$_{PF}$:

The Bayesian posterior ATE_{test} estimate for the Non-Naïve$_{PF}$ fish that reached the tailrace (n = 41) was 77% (95% HDI = 63-88%). There was a greater than 99.9999% posterior probability that the true *ATE* value of the parent population for this group was less than 98%. That is, there was less than 0.0001% 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 0 – 100% (Table 4), and there appeared to be a slight decreasing trend in raw ATE_{test} over time (Figure 7).

Table 4. Passage metrics summarized by release date for 2019. See Table 3 for explanation of notation. Note: Naïve, Non-Naïve and Non-Naïve$_{PF}$ release groups were combined for this table.

Release Date	N	M	T	C	Group raw ATEtest (%)
2/25/2019	1	1	1	1	100%
3/5/2019	2	2	2	2	100%
3/7/2019	1	1	1	1	100%
3/11/2019	2	2	2	2	100%
3/12/2019	2	2	2	2	100%
3/13/2019	1	1	1	1	100%
3/15/2019	4	4	4	4	100%
3/18/2019	4	4	4	4	100%
3/20/2019	3	3	3	3	100%
3/25/2019	10	10	10	10	100%
3/26/2019	6	6	6	6	100%
3/27/2019	6	6	6	6	100%
3/28/2019	1	1	1	0	0%
4/1/2019	7	7	5	5	71%
4/2/2019	6	6	6	2	33%
4/4/2019	2	1	1	1	100%
4/8/2019	10	8	8	8	100%
4/9/2019	1	1	1	1	100%
4/11/2019	1	1	1	1	100%
4/16/2019	11	11	8	8	73%
4/17/2019	2	2	2	2	100%
4/18/2019	6	6	6	6	100%
4/19/2019	10	10	10	7	70%
4/25/2019	5	3	3	2	67%
5/1/2019	3	3	2	2	67%
Total:	**107**	**102**	**96**	**87**	**see Table 3**

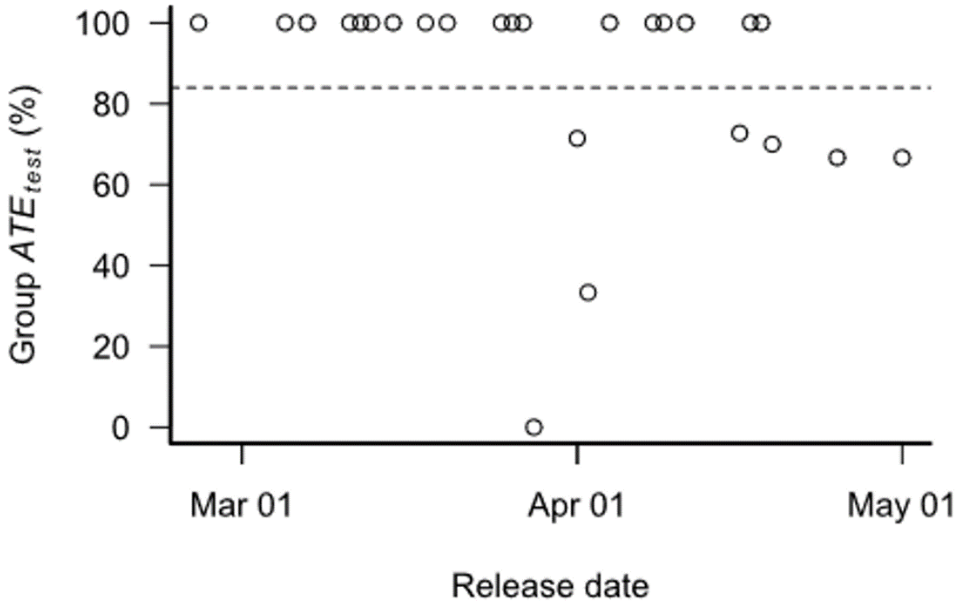

Figure 7. Estimated raw ATE_{test} by date of release. Dashed horizontal line indicates seasonal raw ATE_{test} estimate for winter steelhead in 2019. Open circles are ATE_{test} estimates for all fish released on a given day.

Results from binomial GLMs (logistic regressions) indicated there was a significant effect of release date on raw re-capture probability for all release groups combined ($df = 105$, $p = 0.01$; Figure 8). Despite an apparent visual trend indicating a stronger trend between the probability of recapture and release date for Non-Naïve fish, there was no significant effect of release group on re-capture probability (Figure 8).

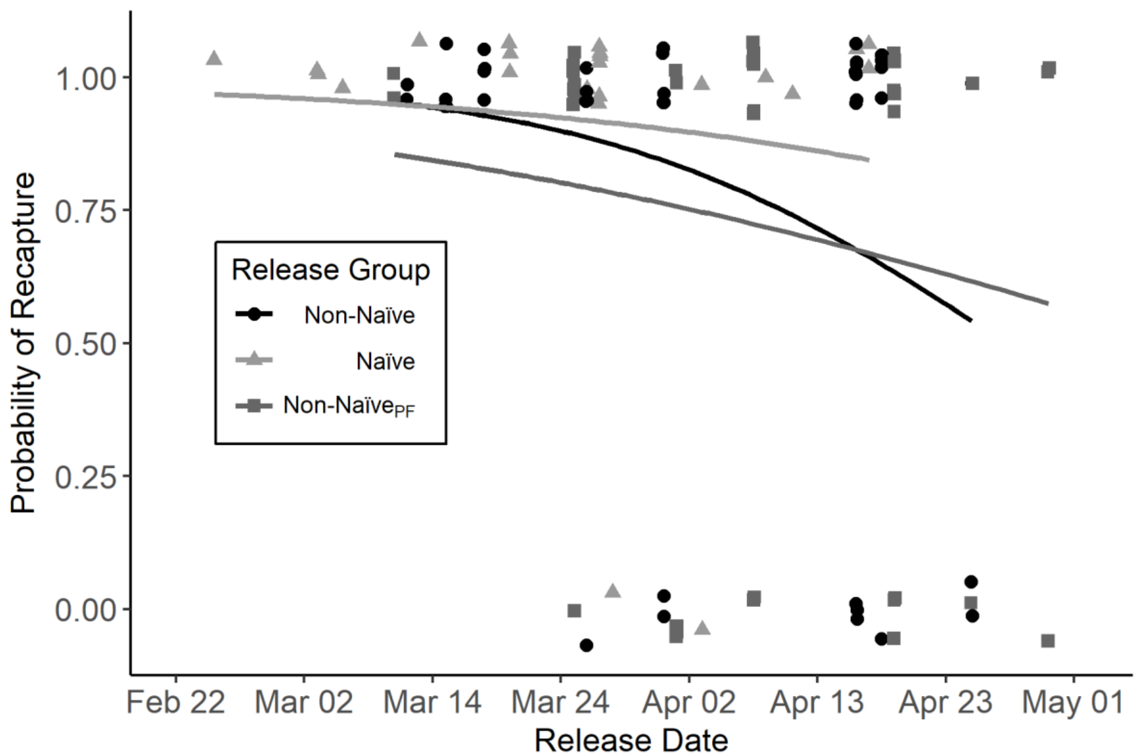

Figure 8. The raw probability of re-capture for individual fish, plotted as a function of release date. Probabilities are jittered for ease of visualization. Black circles, light grey triangles and dark grey squares represent individual fish from the Non-Naïve, Naïve, and Non-Naive$_{PF}$ release groups, respectively. Lines indicate the predicted probability of re-capture across release date based on logistic regression for each release group. Line shading corresponds to shading of shapes for each release group. All fish were included in this figure, not just those fish that reached the tailrace.

Objective 1d: Compare ATE among release groups

The following results are based on Bayesian proportions tests of ATE_{test} among groups (Figure 9):

- Naïve fish exhibited ATE_{test} that was approximately 7 percentage points (95% HDI for this difference is -0.022 – 0.16) greater than Non-Naïve fish. There is a 93% posterior probability that this difference is "real" (i.e., that naïve fish truly exhibited a greater *ATE* than non-naïve fish).
- Naïve fish exhibited ATE_{test} that was approximately 18 percentage points (95% HDI for this difference is 0.047 – 0.33) greater than Non-Naïve$_{PF}$ fish. There is a greater than 99% posterior probability that this difference is real (i.e., that naïve fish truly exhibited a greater *ATE* than Non-Naïve$_{PF}$ fish.
- Non-Naïve fish exhibited ATE_{test} that was approximately 11 percentage points (95% HDI for this difference is -0.022 – 0.25) greater than Non-Naïve$_{PF}$ fish. There is a 95% posterior probability that this difference is real (i.e., that non-naïve fish truly exhibited a greater *ATE* than Non-Naïve$_{PF}$ fish).

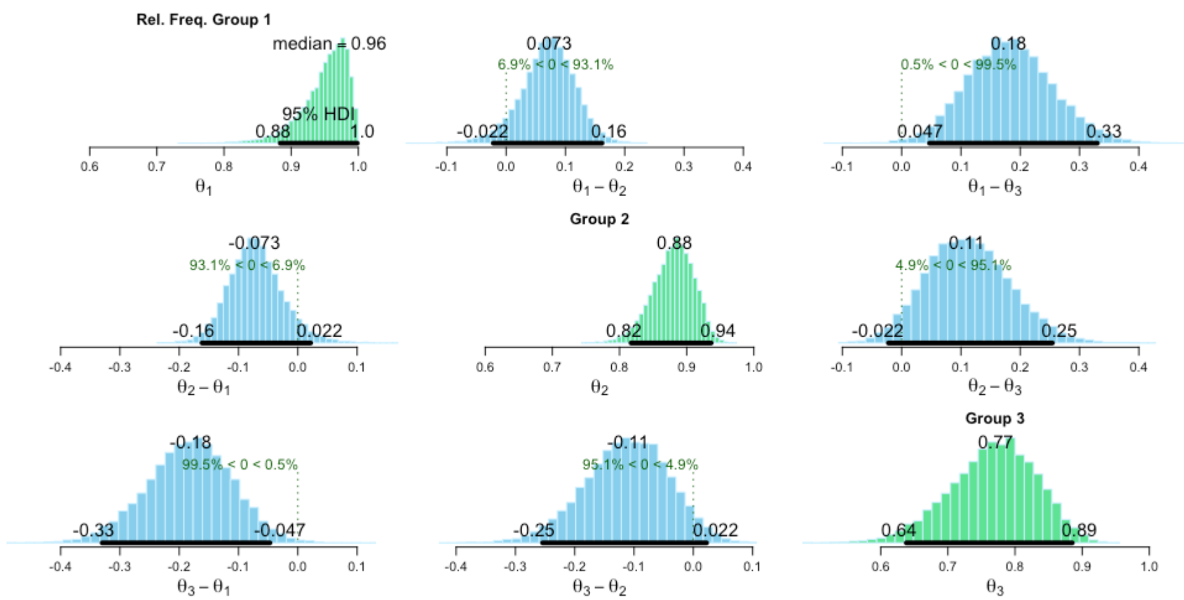

Figure 9. Comparison matrix for ATE_{test} among release groups. Group 1= Naïve, Group 2 = Non-Naïve, and Group 3 = Non-Naïve$_{PF}$. Diagonal panels (green) represent posterior ATE_{test} estimates for each group, with median shown above and 95% HDI shown at bottom of panel. All other panels indicate comparison plots between groups indicated by $\theta_i - \theta_j$. Black numbers above comparison plot distributions (e.g., 0.073) depict posterior estimates of effect size. Green numbers below effect size (e.g., 6.9%<0<93.1%) indicate the direction of the effect, e.g., 93% probability that the difference is greater than zero, 6.9% probability that the difference is less than zero. Black bars and numbers along x-axis of comparison plots indicate 95% HDI for difference among groups. Figure created using Bayesian First Aid package in R (Baath 2014).

Objective 2: Determine if fish show direct movement to the trap entrance; if some fish do not, document their behavior patterns 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. These are comparable to results from 2015-2017. Next, we present results comparing Naïve, Non-Naïve and Non-Naïve$_{PF}$ fish.

Non-Naïve fish

A visual inspection of the network diagram for Non-Naïve steelhead movements throughout the study area illustrates a tendency of fish to move widely within the tailrace (Figure 10). Key findings include the following:

1) Fish entering the tailrace upstream of the Bridge receiver showed no preference for either the South Shore or North Shore (grey lines leaving Bridge and pointing towards SS and NS are similar in shading in Figure 10).
2) The most frequent pathway that resulted in a detection at just outside of the entrance to the trap was from the Powerhouse South (grey lines pointing towards Approach are darkest from PWS in Figure 10).
3) Individuals exhibit milling behaviors (blue lines in Figure 10) in the tailrace, between receivers South Shore ↔ Powerhouse South, and near the entrance to the trap, between receivers Approach ↔ Entrance.
4) There was a large amount of milling behaviors within the trap.

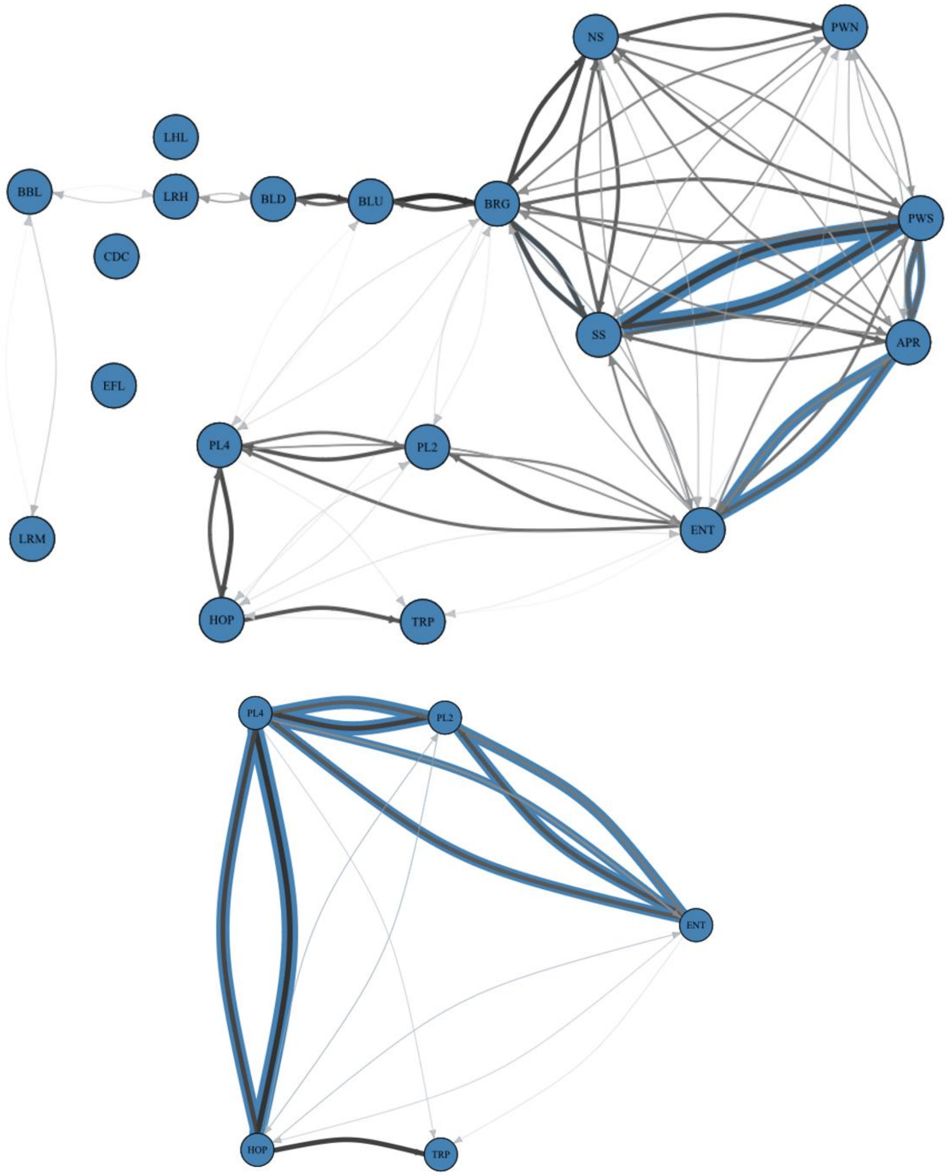

Figure 10. Network diagram of Non-Naïve fish movement within study area. Path thickness and color are scaled based on the total number of individual fish traveling the paths (thicker paths represent a higher number of fish taking the path at least one time across their detection history). Grey paths 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 11). Within this figure, a stair-step pattern is apparent from the upper left to the bottom right, suggesting that fish generally move 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 75%) site.
2) Once a fish progressed to the Bridge site, it had a 33% probability of next being detected at the South Shore site, which was nearly double the probability of next being detected at either the North Shore site (17%) or the Boat Launch Upstream site (19%).
3) When fish were at any of the Boat Lunch Downstream, Boat Launch Upstream or South Shore sites, there was a high probability of being detected next at the site that was immediately upstream: 90% for BLD, 73% for BLU, and 64% for SS.
4) Once a fish was detected at the Bed & Breakfast site, there was an 71% probability of next being detected at the Lewis River Mouth site.
5) Once a fish had been detected at the trap Entrance receiver, there was a 79% probability of being next detected somewhere in the tailrace compared to only a 21% probability of being next detected further upstream into the trap ladder.
6) Once a fish was inside the trap and detected in Pool 2, there was a 55% probability of the fish being detected next at a site that was further into the trap, and a 41% probability of fish being detected at the Entrance site.

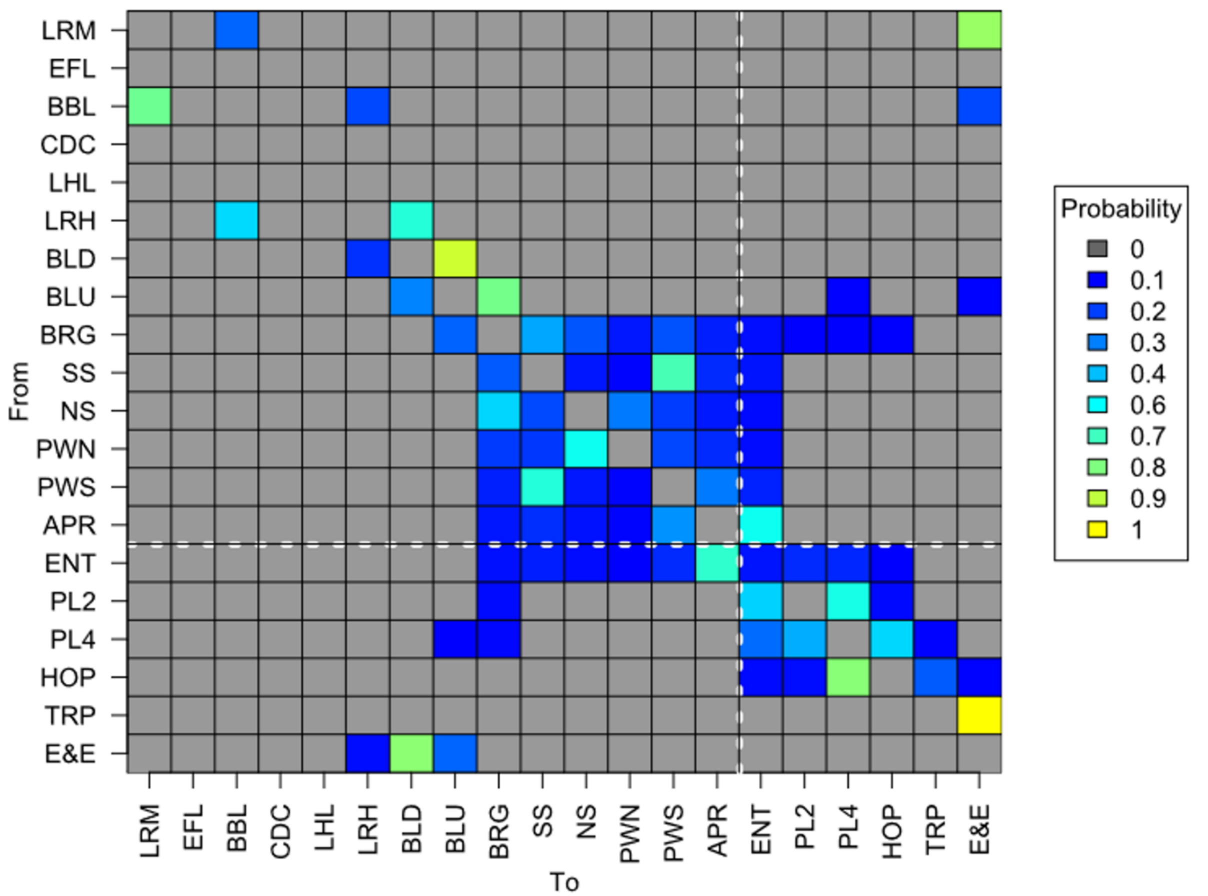

Figure 11. Heat map of the transition probabilities of Non-Naïve fish moving from an origin site to all potential destination sites. Each row sums to a probability of 1. Dashed reference lines are added between the Approach and Entrance receivers to show the distinction of a fish being located within 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)

When considering the number of unique site visits by each fish, it appears that fish that were eventually trapped visited more than double the number of sites compared to fish that were never trapped, suggesting that fish do not tend to move directly into the trap (Figure 12). The median number of sites visited for fish that were eventually trapped was 103 (mean = 275), compared to median value of only 40 (mean = 78) unique site visits for fish that were not trapped.

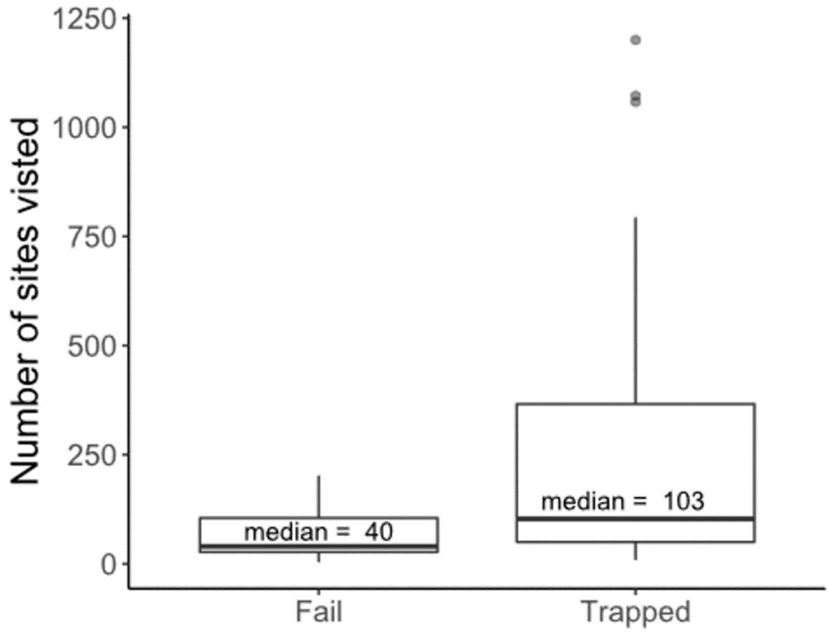

Figure 12. Number of sites visited before being captured (Trapped) or in the case of fish that were not captured, before the end of the study (Fail).

In general, fish tended to move upstream through the 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 move upstream along the South Shore or North Shore sites, until they reached further into the tailrace at the Powerhouse (i.e., PWN and PWS) sites.
- Once at the Powerhouse North, Powerhouse South, and Approach sites, fish had lower probabilities of transitioning to the next upstream site and there was more milling behavior between these sites.
- Once inside the trap, there were also low probabilities of fish transitioning forward (except from Pool 2) and more milling behaviors.
- 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.

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} less than 0.5 are shaded blue, and *MI* greater than 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*). 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).

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	0.200	0.200	0.000	NA	NA	NA	0.200	0.200	0.000
BBL	0.143	0.143	0.000	NA	NA	NA	0.143	0.143	0.000
LRH	0.167	0.143	0.024	1.000	1.000	0.000	0.583	0.571	0.012
BLD	0.538	0.846	-0.308	0.844	0.930	-0.086	0.756	0.904	-0.148
BLU	0.467	0.508	-0.041	0.633	0.788	-0.155	0.594	0.733	-0.139
BRG	0.774	0.746	0.028	0.822	0.813	0.009	0.813	0.805	0.008
SS	0.583	0.658	-0.074	0.617	0.784	-0.167	0.612	0.776	-0.165
NS	0.571	0.506	0.065	0.525	0.422	0.103	0.533	0.434	0.100
PWN	0.067	0.026	0.040	0.169	0.124	0.045	0.149	0.109	0.039
PWS	0.263	0.407	-0.144	0.369	0.301	0.069	0.354	0.308	0.045
APR	0.111	0.022	0.089	0.255	0.559	-0.304	0.232	0.526	-0.294
ENT	0.400	0.500	-0.100	0.366	0.163	0.203	0.368	0.165	0.203
PL2	1.000	1.000	0.000	0.600	0.563	0.037	0.608	0.565	0.043
PL4	0.250	0.556	-0.306	0.471	0.425	0.046	0.458	0.428	0.030
HOP	0.000	0.000	0.000	0.467	0.188	0.279	0.452	0.181	0.271

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 13). However, within the tailrace, spatial behavior patterns were similar between successfully and unsuccessfully re-captured fish.

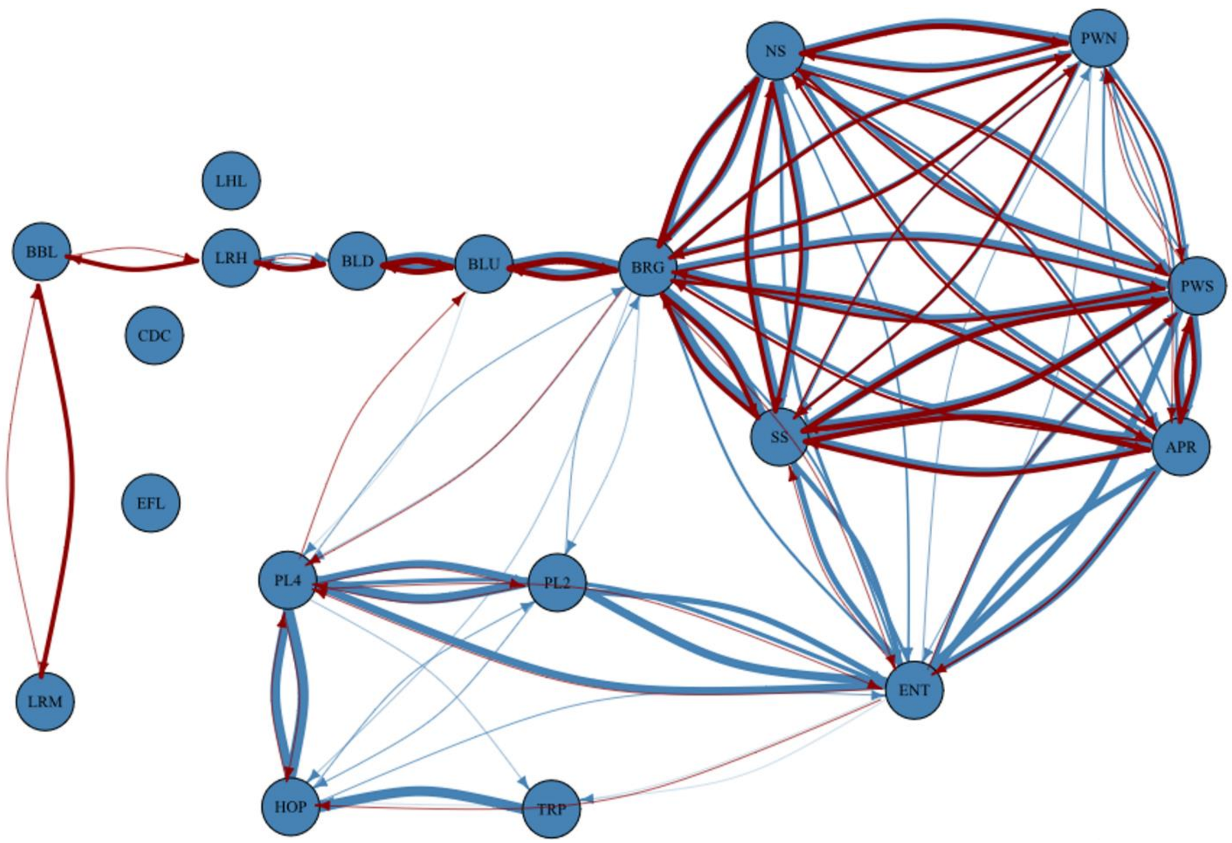

Figure 13. Network diagram of Non-Naïve fish movement within the study area at Merwin Dam grouped by fish that ultimately are re-captured (blue) or failed to be re-captured (red) from 2019. Path thickness and color are scaled based on the total number of transitions which occurred between sites with fish as the sample unit. This figure 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 among release groups

Comparisons of the numbers of sites visited prior to being trapped among release groups showed Non-Naïve fish visited over two times the number of sites on average (mean = 275) compared to Naïve fish (mean = 110) and Non-Naive$_{PF}$ fish (mean = 111).

Despite apparent differences in mean numbers of sites visited among release groups (Figure 14), results from Wilcoxon rank sum tests comparing the median number of unique site visits between release groups found no significant differences among release groups.

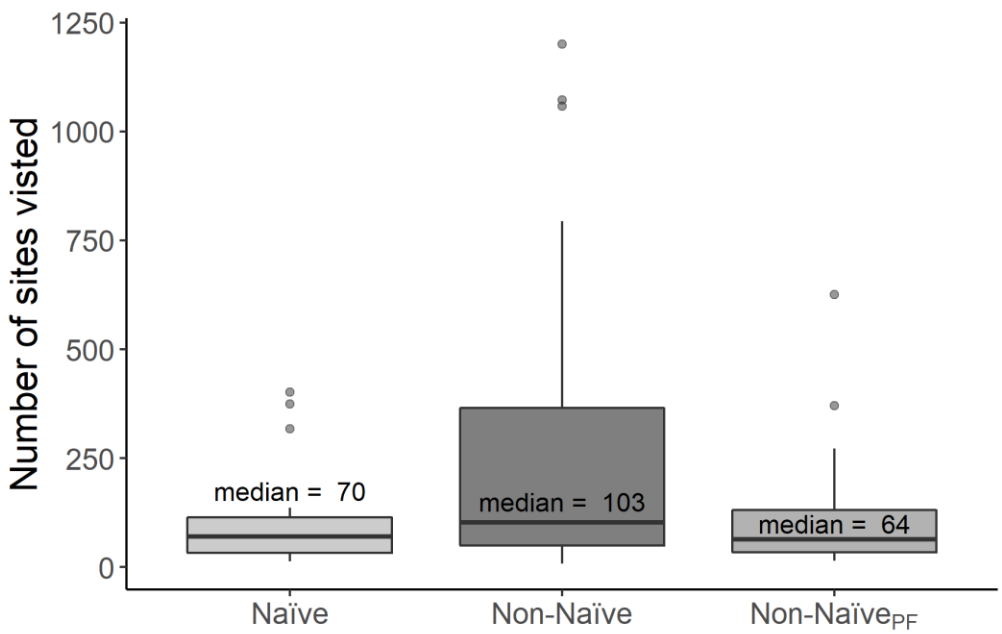

Figure 14. Number of sites visited before being trapped for Naïve and Non-Naïve fish.

Compared to Naïve and Non-Naïve$_{PF}$ fish, Non-Naïve fish exhibited more milling behavior after entering the trap entrance (Table 6). Apart from these differences, the probabilities of transitioning to the next upstream site were generally similar among release groups (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} less than 0.5 are shaded blue, and *MI* greater than 0.000 are shaded green. P_{single} *and* P_{all} values are provided for Naïve, Non-Naïve and Non-Naive$_{PF}$ fish. 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).

Receiver	P_{single} (Non-Naïve)	P_{all} (Non-Naïve)	*MI* (Non-Naïve)	P_{single} (Naïve)	P_{all} (Naïve)	*MI* (Naïve)	P_{single} (Non-Naïve$_{PF}$)	P_{all} (Non-Naïve$_{PF}$)	*MI* (Non-Naïve$_{PF}$)
LRM	0.200	0.200	0.000	0.500	0.500	0.000	0.500	0.500	0.000
BBL	0.143	0.143	0.000	0.429	0.500	-0.071	0.429	0.500	-0.071
LRH	0.583	0.571	0.012	0.778	0.545	0.232	0.778	0.545	0.232
BLD	0.756	0.904	-0.148	0.792	0.910	-0.118	0.792	0.910	-0.118
BLU	0.594	0.733	-0.139	0.656	0.532	0.124	0.656	0.532	0.124
BRG	0.813	0.805	0.008	0.835	0.778	0.057	0.835	0.778	0.057
SS	0.612	0.776	-0.165	0.554	0.744	-0.190	0.554	0.744	-0.190
NS	0.533	0.434	0.100	0.483	0.414	0.068	0.483	0.414	0.068
PWN	0.149	0.109	0.039	0.194	0.145	0.048	0.194	0.145	0.048
PWS	0.354	0.308	0.045	0.418	0.406	0.012	0.418	0.406	0.012
APR	0.232	0.526	-0.294	0.224	0.351	-0.127	0.224	0.351	-0.127
ENT	0.368	0.165	0.203	0.429	0.346	0.082	0.429	0.346	0.082
PL2	0.608	0.565	0.043	0.594	0.673	-0.080	0.594	0.673	-0.080
PL4	0.458	0.428	0.030	0.512	0.620	-0.109	0.512	0.620	-0.109
HOP	0.452	0.181	0.271	0.421	0.095	0.326	0.421	0.095	0.326

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, higher median residence times, and greater total time spent 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, Powerhouse South 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 these sites compared to the North Shore and Powerhouse North sites (Figure 15).
2) Fish visited the South Shore and Powerhouse South sites more than any other site in the trailrace, approximately four times as many visits at these sites compared to the North Shore and Powerhouse North sites (Figure 15).
3) Fish also spent large amounts of time holding at the South Shore and Powerhouse South sites based on high median residence times at these sites (Figure 15).
4) Fish did not visit the Powerhouse North site frequently, and when fish did visit the Powerhouse North site, they did not spend time holding at these sites (Figure 15; Figure 16).
5) Within the tailrace, fish spent large amounts of time holding at the Bridge site followed by the Powerhouse South site based on high median residence time and total time spent at these sites (Figure 15; Figure 16).
6) Once in the trap, fish spent the most time holding inside Pool 2 and Pool 4 based on the relativley high median residence times and relatively low number of site visits at these sites (Figure 15).
7) Behavioural trends were generally similar among release groups with all release groups using the south side of the tailrace more than the north side (Figure 15; Figure 16).
8) Compared to Naïve and Non-Naive$_{PF}$ fish, Non-Naïve fish visited more sites within the tailrace, but the median residence times at sites were similar among release groups.
9) In the trap, Non-Naive$_{PF}$ fish visited many sites (Figure 15), spending most of their time at the Hopper site (Figure 16), whereas Naïve and Non-Naïve fish spent more time in Pool 2 and Pool 4 than at the Hopper site (Figure 16).

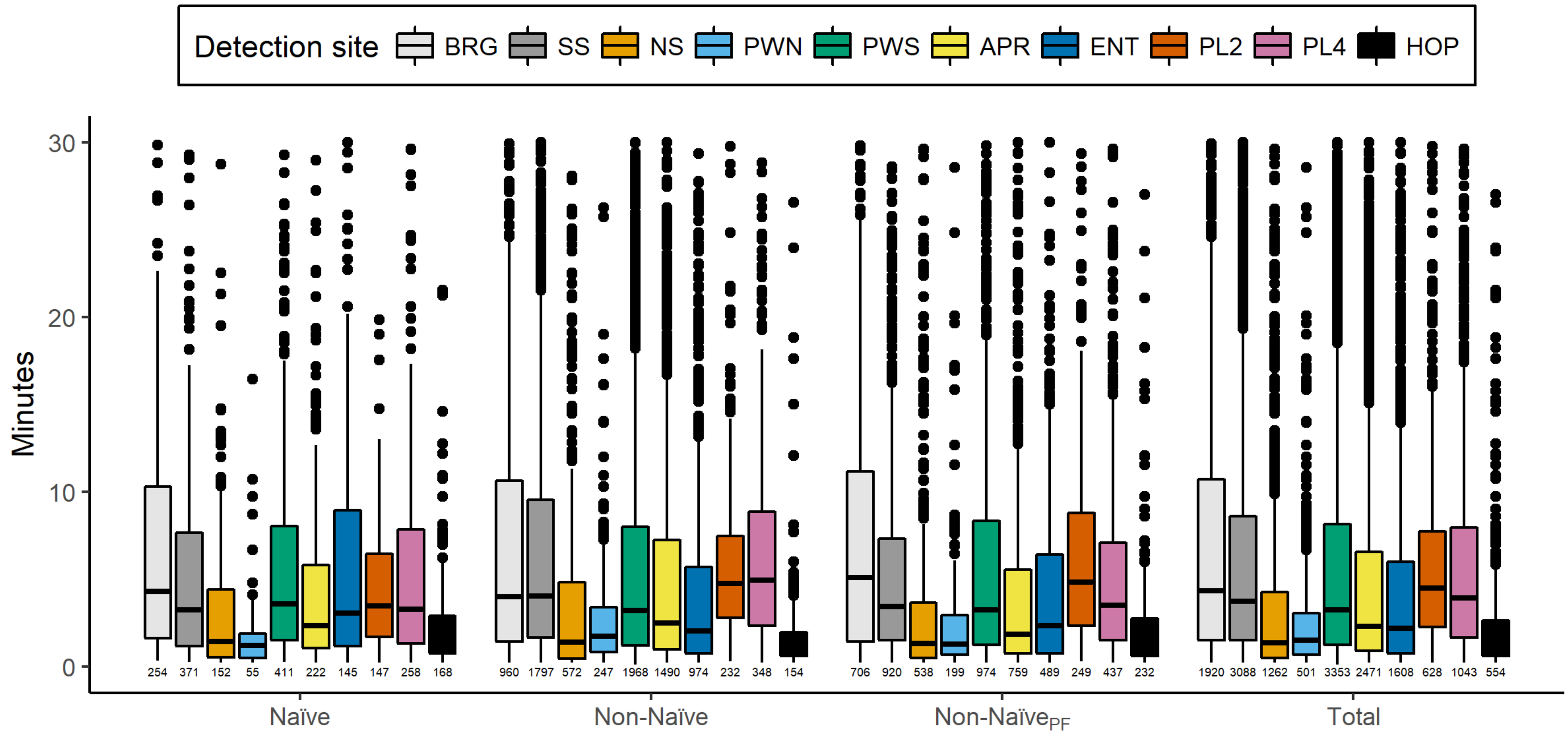

Figure 15. Median time spent by individual fish at each receiver site (residence times) plotted for all sites in the tailrace and trap. The figure is zoomed in to show the box and whisker plots, focusing on inter-quartile range, which excludes outliers (shown in closed circles) for residence times greater than 30 minutes. 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).* 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).

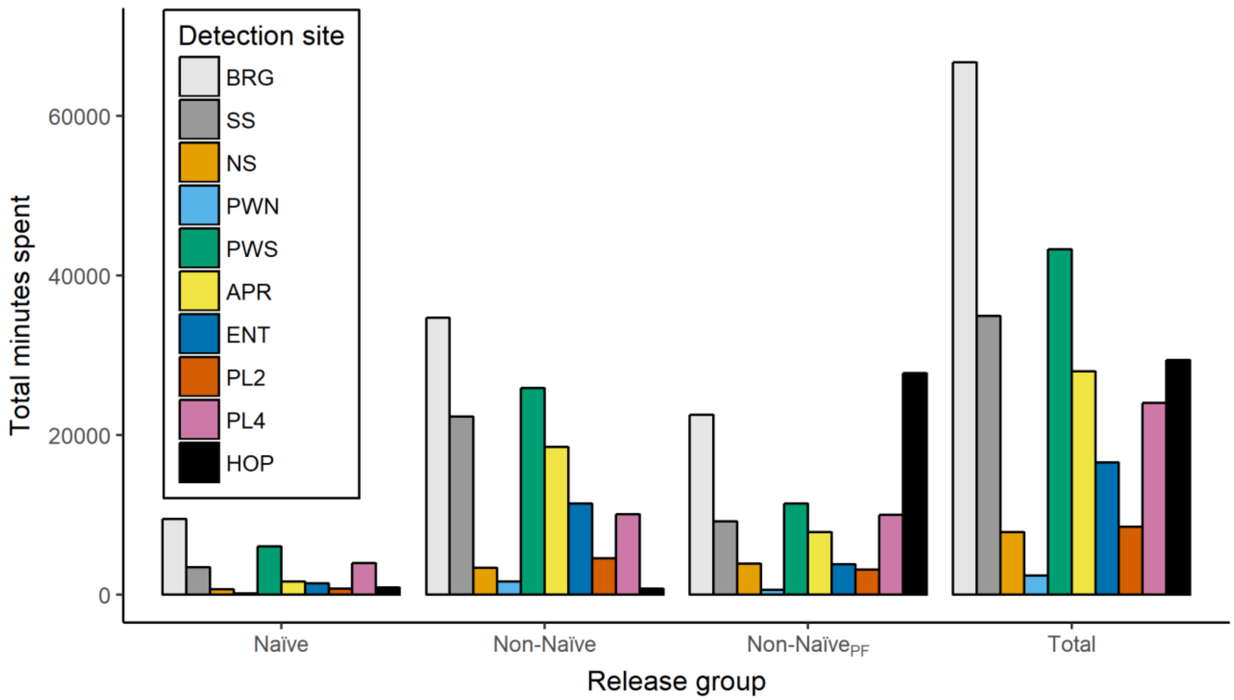

Figure 16. Total time spent by steelhead in each site in the tailrace and trap. Data are separated by release group. Note: Sample sizes differ between release groups, therefore, direct comparisons of total time spent at each site among release groups is not appropriate. *Caveat: these data are not scaled based on the detection ranges of each site*. Abbreviations are given for sites as follows: 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

The following inferences can be drawn from behavioral observations at sites downstream of the tailrace.

- Non-Naïve fish held near the Lewis River Hatchery and Boat Launch Downstream locations based on a low number of detections and high median residence at these locations (Figure 17).
- Naïve fish also held near the Lewis River Hatchery, and to a lesser extent the Boat Launch Downstream site, based on low numbers of detections and high median residence times at these sites.
- Non-Naïve$_{PF}$ fish spent less time than the other groups holding at the Lewis River Hatchery based on lower median residence time (Figure 17) and lower overall total time spent at this site.
- Naïve fish spent the largest amount of time at the Lewis River Hatchery site (138,279 minutes or approximately 96 days, approximatey 35% of total time within the array), which was the closet receiver location to where Naive fish were released (Figure 18).
- Similarly, Non-Naïve fish also spent the largest amount of time at the site downstream from their release locaiton, the Boat Launch Downtream site (352,530 minutes or approximately 245 days, approximatley 40% of total time within the array; Figure 18).
- Non-Naïve$_{PF}$ fish spent the largest amount of time (144,228 or approximately 100 days, approximately 33% of total time within the array) at the Boat Launch Downstream site (Figure 18), despite being released near the confluence of the Lewis River and Columbia Rivers, which is approximately28 km downstream from the Boat Launch Downstream site.

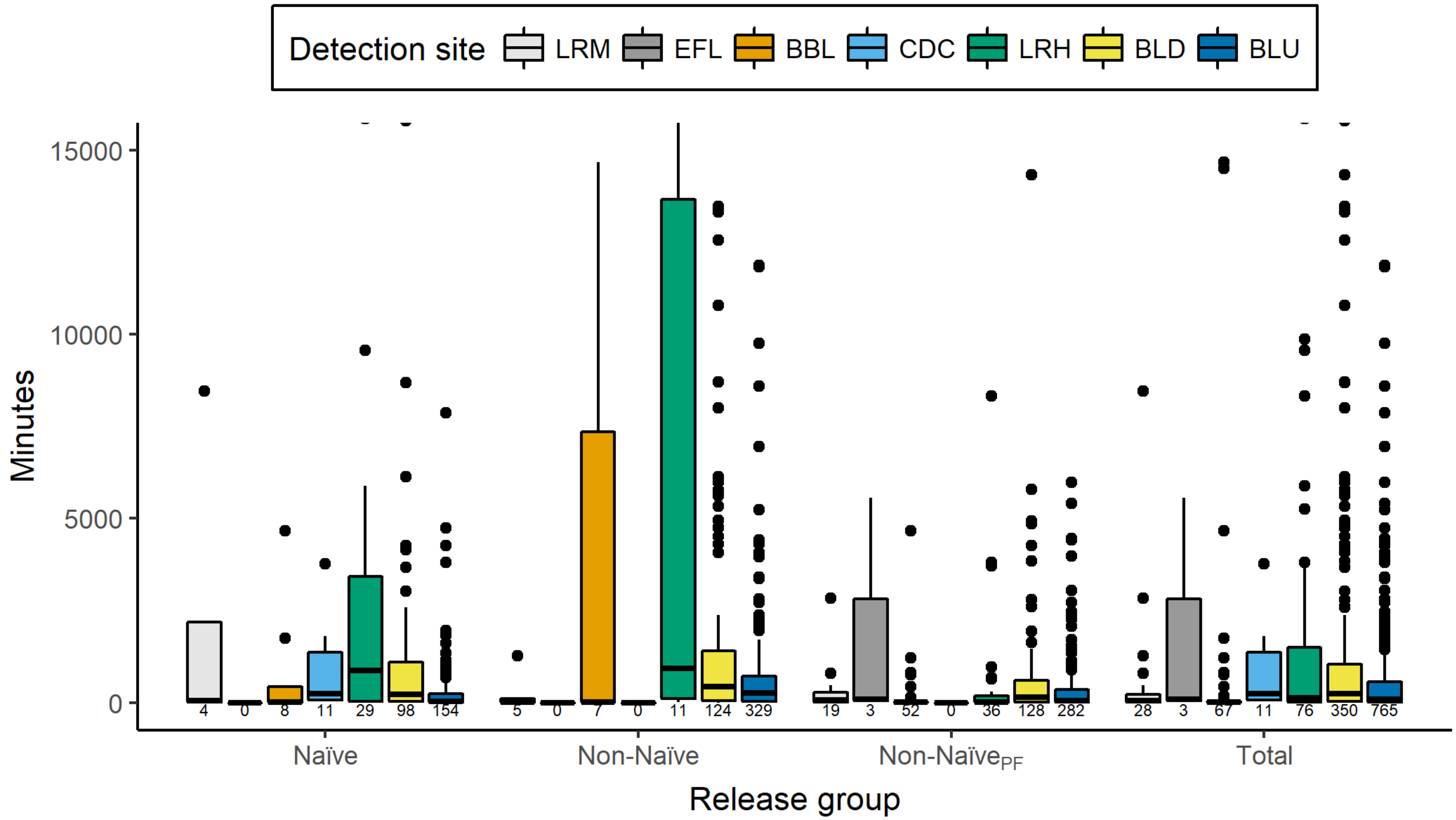

Figure 17. Median residence times for downriver sites. The figure is zoomed in to show the box and whisker plots, focusing on inter-quartile range, which excludes outliers (shown in closed circles) for residence times greater than 22,000 minutes from the figure. Data are separated by release group. Number of visits is displayed below boxplots. (*Caveat: these data are not scaled based on the detection ranges of each site.*). 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).

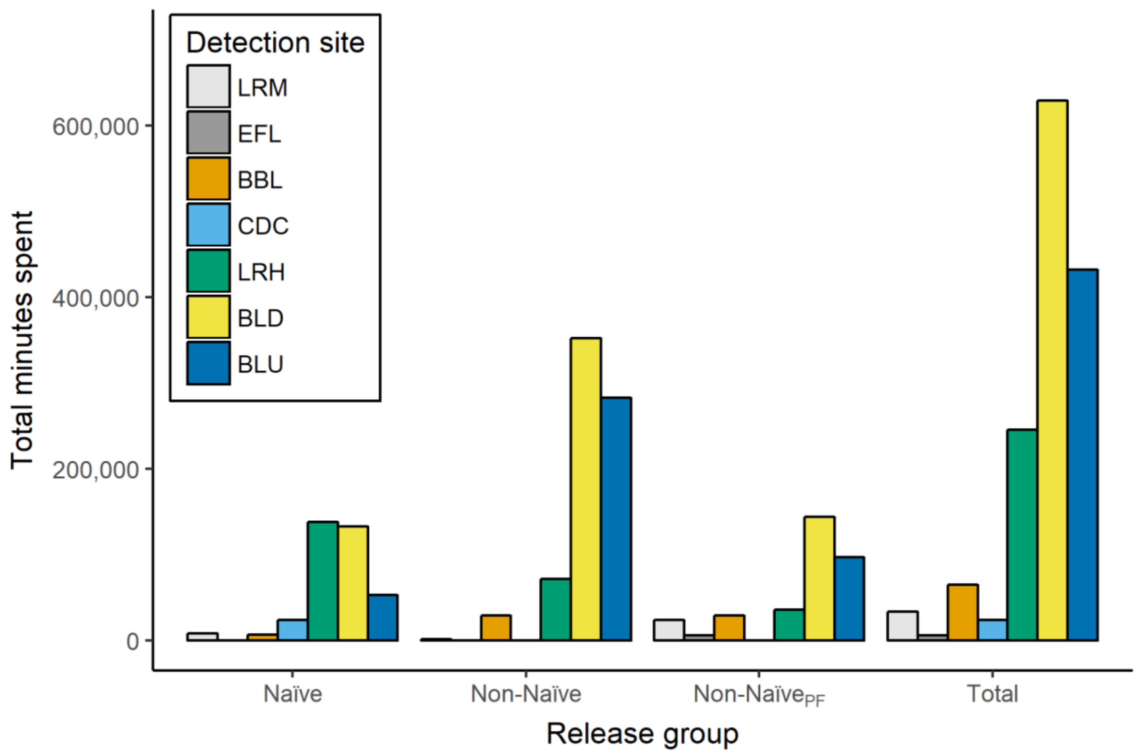

Figure 18. Total time spent by steelhead in each downriver site. Data are separated by release group. Note: Sample sizes differ between release groups, therefore, direct comparisons of total time spent at each site among release groups is not appropriate. *Caveat: these data are not scaled based on the 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

When combined among all three groups, the median tailrace residence time for steelhead in the Merwin Dam tailrace was 22.6 hours (range = 2 minutes – 292 hours) (Table 7). The lower end of this range represents a fish that was 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$_{PF}$ fish exhibited median tailrace residence times less than 24 hours (Table 7), thus achieving the performance standard for median tailrace residence time. Non-Naïve fish exhibited median tailrace residence time greater than 24 hours (Table 7), thus not achieving the performance standard for median tailrace residence time.

Seven steelhead (approximately 7% of the 102 fish that entered the tailrace) exhibited tailrace residence times greater than 168 hours (seven days, Table 7). This exceeds the performance standard of less than 5% of fish taking longer than 168 hours to pass the tailrace. Of the seven steelhead that took longer than 168 hours to pass the tailrace, four were Non-Naïve fish and three were Non-Naïve$_{PF}$ fish, both of which resulted in greater than 5% of fish from these release groups taking longer than 168 hours to pass (Table 7). None of the Naïve fish exhibited tailrace residence times greater than 168 hours (Table 7). Thus, performance standard compliance metrics for safe, timely, and effective passage were not met for both Non-Naïve and Non-Naïve$_{PF}$ fish but were met for Naïve fish.

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

Table 7. Achieved performance standard compliance metrics for safe, timely, and effective passage of winter steelhead at Merwin Dam in 2019. Numbers of fish that entered the tailrace are presented (*M*) for each group. Metrics are also presented separately for Naïve, Non-Naïve and Non-Naïve$_{PF}$ fish.

Study Year	Species/Release Group	*M*	Median Tailrace Residence (range)	Percentage of Fish with Tailrace Residence Time > 168 hrs
2019	winter steelhead	102	22.6 hrs (0.03-292.0 hrs)	7%
	Naïve	*22*	*15.4 hrs (1.4-74.0 hrs)*	*0%*
	Non-Naïve	*39*	*28.9 hrs (0.03-292.0 hrs)*	*10%*
	Non-Naïve$_{PF}$	*41*	*17.8 hrs (1.1-250.9 hrs)*	*7%*

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

- Seventy-eight steelhead with detections in the tailrace were captured successfully.
  - These fish exhibited a median tailrace residence time of 19 hours (range = 0.8 – 292 hours)
  - Five of these fish (6%) exhibited tailrace residence time greater than 168 hours.
- Sixteen steelhead detected in the tailrace were never captured.
  - These fish exhibited a median tailrace residence time of 33 hours (range = 0.03 – 223 hours)
  - Two of these fish (12.5%) exhibited tailrace residence time greater than 168 hours.

Wilcoxon rank sum tests indicated Non-Naïve fish displayed significantly higher median tailrace residence time compared to Naïve (W = 181, p = 0.02) and Non-Naïve$_{PF}$ (W =571, p = 0.04) fish, but there were no differences between Naïve and Non-Naïve$_{PF}$ fish (W =253, p = 0.79). On average, Naïve and Non-Naïve$_{PF}$ fish spent approximately 45 and 35 fewer hours in the tailrace prior to being recaptured, respectively, compared to Non-Naïve fish (Figure 19).

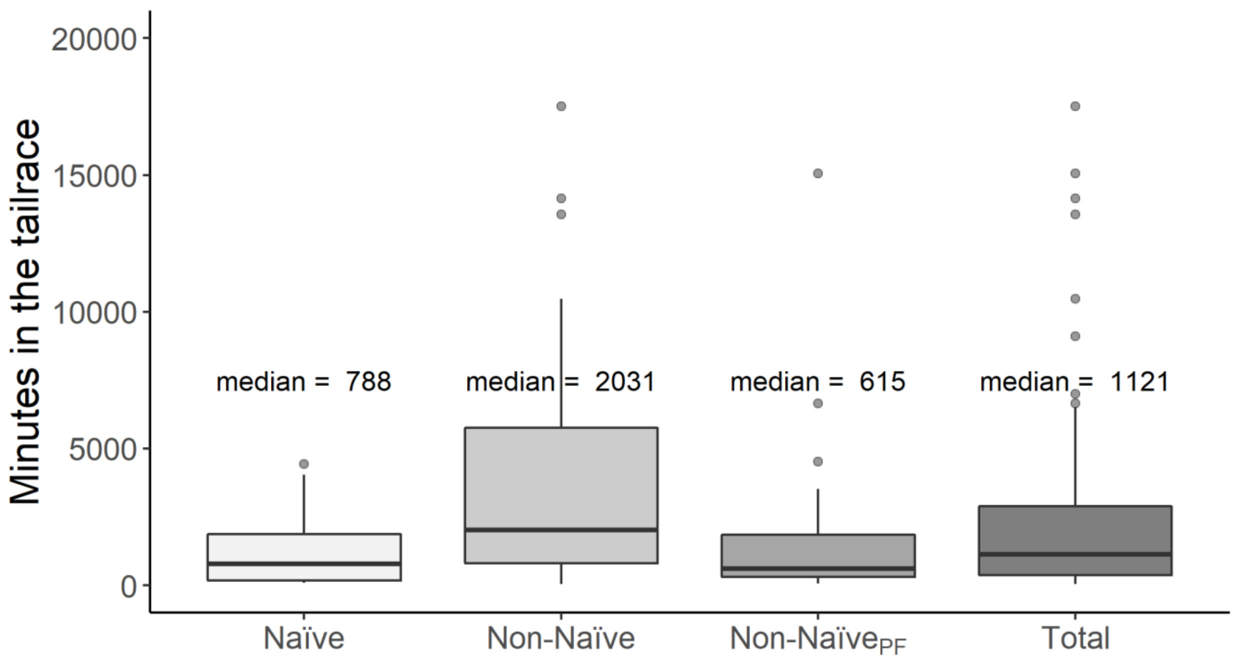

Figure 19. Boxplot showing the number of minutes in the tailrace prior to passing for Naïve, Non-Naïve and Non-Naïve$_{PF}$ fish. A 'Total' group is also presented which combines all release groups. Fish that experienced tag shed or tag failure prior to being captured are not included in this figure.

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

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

Non-Naïve fish

All 41 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 41 fish. However, it should be noted that the numbers presented below do not account for fish that shed their tags 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 41.

Of the 41 Non-Naïve fish detected somewhere in the study area:

- 38 fish (93%) were detected somewhere in the tailrace. Of these 38 fish detected somewhere in the tailrace,
    - 30 fish (79%) returned to downriver sites (i.e., below the access bridge)
        - 25 of these 30 (83%) were eventually successfully captured
        - Five fish were not captured
    - 33 fish (87%) were detected somewhere in the trap ladder system. Of these 33 fish that were detected in the trap ladder,
        - 23 fish (70%) returned to the tailrace after first visiting the trap
            - Four of these fish never made it past the Entrance before exiting.
            - All 23 fish (100%) that exited the trap back into the tailrace after their first post-tagging encounter with the trap were eventually captured.
- 7 fish (17%) were not re-captured but were detected somewhere in the study area (Table 8).
    - Four of these seven fish were last detected at the furthest downstream site, the Lewis River Mouth, and one fish each was last detected at the Bed & Breakfast, Boat Launch Upstream and Bridge sites.
    - ***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, tag regurgitation, or angling capture following detection at this site.*

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

Site of Last Detection	n
Lewis River Mouth	4
Bed & Breakfast	1
Boat Launch Upstream	1
Bridge	1
Total	**7**

Naïve fish

Twenty-two of the 23 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 inferences can be made on the movements of these 22 fish with detection data available. However, 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 22.

Of the 22 Naïve fish detected somewhere in the study area:

- 21 fish (95%) were detected somewhere in the tailrace. Of these 21 fish detected somewhere in the tailrace,
    - 14 fish (67%) returned to downriver sites (i.e., below the access bridge)
        - One (7%) of these 14 fish was never successfully recaptured
        - The remaining 13 (93%) fish were eventually recaptured.
    - All 21 fish (100%) were detected somewhere in the trap ladder system. Of these 21 fish that were detected in the trap ladder,
        - 13 fish (62%) returned to the tailrace after first visiting the trap
            - 12 of these 13 fish (92%)made it past the fyke at the entrance to Pool 2 before exiting.
            - 12 of these 13 fish (92%) were eventually successfully captured
            - One fish (8%) was not captured.
- Two fish (9%) were not re-captured but were detected somewhere in the study area.
    - Both of the two fish not re-captured were last detected at the Lewis River Mouth 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 9. Last known location for the two Naïve fish that were not re-captured but were detected somewhere in the telemetry array.

Site of Last Detection	n
Lewis River Mouth	2
Total	**2**

Non-Naïve$_{PF}$ fish

Forty-two of the 43 tagged Non-Naïve$_{PF}$ 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 42 fish with detection data available. However, 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 42.

Of the 42 Non-Naïve$_{PF}$ fish detected somewhere in the study area:

- 39 fish (93%) were detected somewhere in the tailrace. Of these 39 fish detected somewhere in the tailrace,
    - 29 fish (74%) returned to downriver sites (i.e., below the access bridge)
        - Nine of these fish (31%) were never successfully re-captured
        - The remining 20 fish (69%) were eventually re-captured.
    - A total of 38 fish (97%) were detected somewhere in the trap ladder system. Of these 38 fish that were detected in the trap ladder,
        - 27 fish (71%) exited the trap to the tailrace after first visiting the trap
            - 23 of these 27 fish (85%) made it past the fyke at the entrance to Pool 2 before exiting.
            - 19 of these 27 fish (70%) were eventually successfully recaptured
            - Eight fish (30%) were not re-captured.
- 10 fish (24%) were not re-captured but were detected somewhere in the study area (Table 10).
    - Seven of the 10 Non-Naïve$_{PF}$ fish that were not captured were last detected at the Lewis River Mouth site.
    - Of the remaining three fish not re-captured, one was detected at each of the Bed & Breakfast, Lewis River Hatchery and Boat Launch Downstream sites.
    - ***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 10. Last known location for the seven Non-Naïve$_{PF}$ fish that were not re-captured but were detected somewhere in the telemetry array.

Site of Last Detection	n
Lewis River Mouth	7
Bed & Breakfast	1
Lewis River Hatchery	1
Boat Launch Downstream	1
Total	**10**

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.

Fish energetic state

The percent muscle lipid content of fish used in the study ranged from 0.9 – 4.6 % (mean ± SD = 1.8 ± 0.8 %). There was a significant negative relationship between tagging date and muscle lipid content of fish (df = 103; $p < 0.001$). This trend indicated that 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 a modest amount of the variability in muscle lipid content (adjusted R^2 = 0.20). All release groups exhibited a similar negative relationship between release date and muscle lipid content (Figure 20), and there were no significant differences in muscle lipid content among release groups.

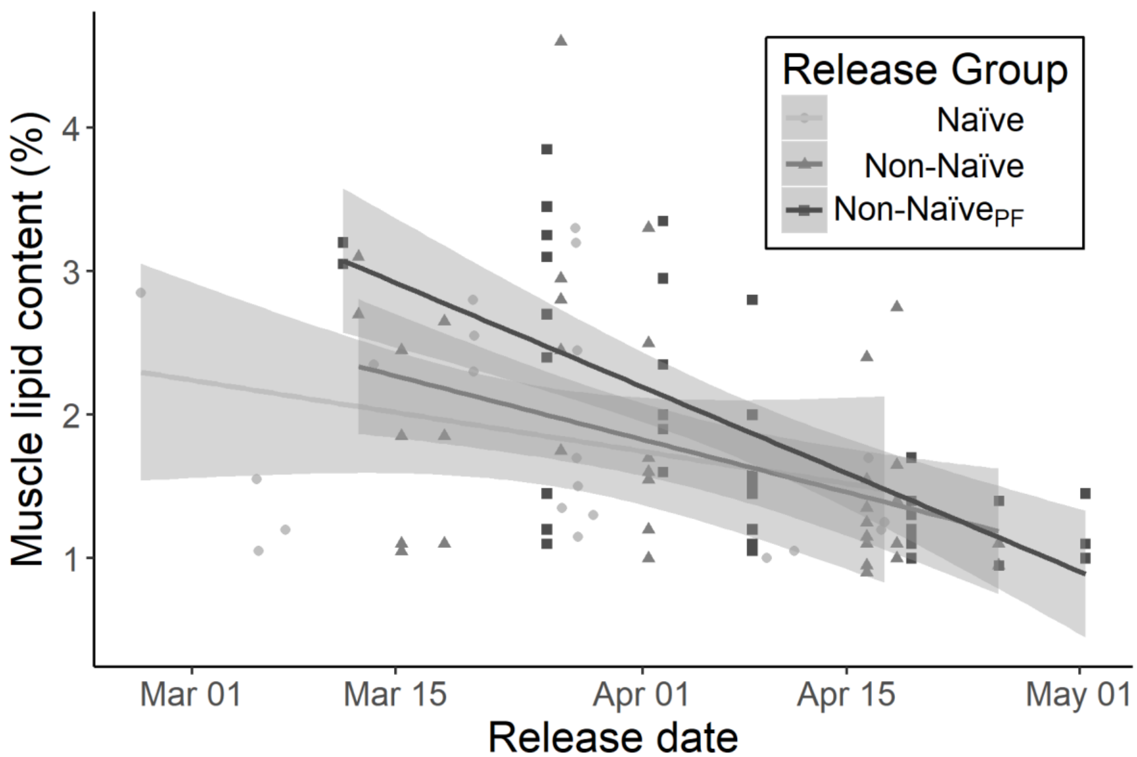

Figure 20. Muscle lipid content of individual steelhead by release date. Shading and symbols indicate individual fish release group (Naïve = light grey, circles; Non-Naïve = dark grey, triangles; Non-Naïve$_{PF}$ = black, squares). Lines are based on linear regression and shaded areas around lines represent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

The linear model comparing muscle lipid content between sexes and between trapped and not trapped fish indicated males had significantly higher muscle lipid content than females (df = 101, $p = 0.008$). On average, males exhibited 1.6 times greater muscle lipid content compared to female fish. Although trapped fish appeared to have greater muscle lipid content than not trapped fish (Figure 21), this difference was not significant (ANOVA, df = 101, $p = 0.3$).

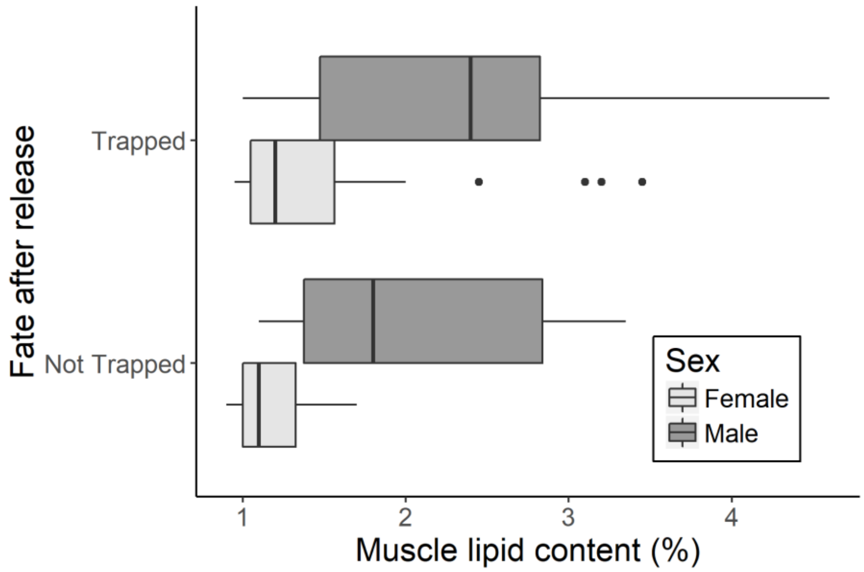

Figure 21. Box and whisker plot of the muscle lipid content of fish that were trapped versus fish that were not trapped separated by sex at the Merwin Fish Collection Facility after release. All release groups were combined.

When consumption of stored somatic energy was calculated as the difference between muscle lipid content measured prior to release and again following re-capture at Merwin Dam, Non-Naïve fish used the most energy (mean ± sd = 0.7 ± 0.8 %) among release groups after release, followed by Non-Naïve$_{PF}$ fish (mean ± sd = 0.6 ± 0.6 %) and Naïve fish (mean ± sd = 0.04 ± 0.1 %) (Figure 22). Linear models used to test for differences in energy consumption between release groups indicated significantly greater energy consumption for both Non-Naïve (df = 26; p = 0.03) and Non-Naïve$_{PF}$ (df = 14; p = 0.04) fish compared to Naïve fish, but there were no differences between Non-Naïve and Non-Naïve$_{PF}$ fish (Figure 22). On average, Naïve fish consumed 17.5- and 15-fold less energy compared to Non-Naïve and Non-Naïve$_{PF}$ fish, respectively.

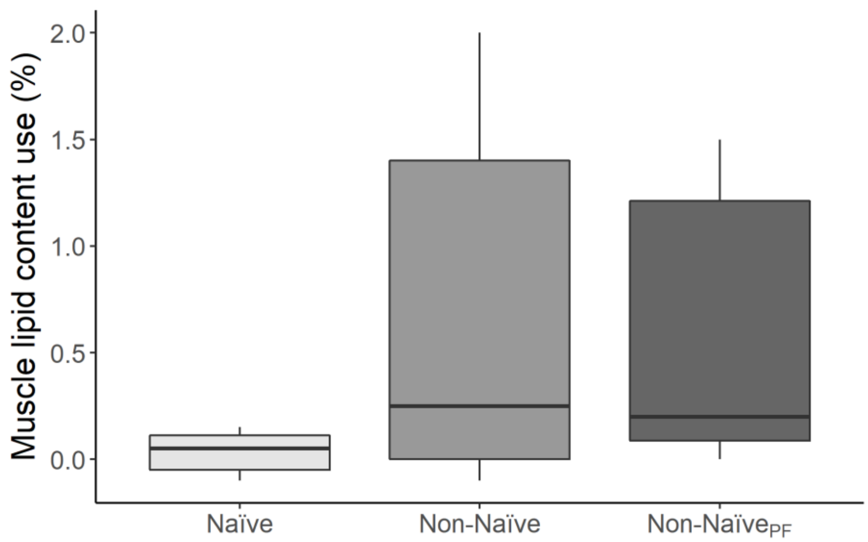

Figure 22. Difference in muscle lipid content (energy consumption) for each release group, calculated as difference in measured value at the time of release and again when re-captured at Merwin Dam. Greater muscle lipid content use indicates fish used more energy after release.

Reflex impairment

Impairment of five different reflexes was assessed for all 107 fish before they were released. Of these 107 fish:

- 95 (89%) had zero impaired reflexes out of the five reflexes assessed.
- 12 (11%) fish had one or more reflexes impaired
    - Five of these 12 fish had two reflexes impaired
        - These five fish with more than one reflex impaired were Non-Naïve fish
        - All but one of these fish were eventually re-captured
    - Seven of these 12 fish had one reflex impaired
        - Six of these seven fish with one reflex impaired were eventually 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 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.

Similar to the 2018 ATE study, no trap-induced injuries were observed on any of the fish that were recaptured at Merwin Fish Trap in 2019. There were, however, two recaptured fish that exhibited pinniped-induced injuries. Because this source of injury are not trap related, these injuries were not included in the injury assessment. Additionally, no mortalities were observed of the 86 fish that were recaptured. It was therefore determined that there was an observed injury rate of 0%, and a transport survival rate of 100% for BWT steelhead in 2019.

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

Total NF Lewis River discharge in 2019 was initially low (approximately 2,000 cfs) at the start of tagging in February, then exhibited two peaks before decreasing again and remaining low (Figure 23). In early March, flow reached approximately 10,000 cfs, before returning to base flow until early April, when flow began increasing to a peak of greater than 10,000 cfs in mid-April. After this mid-April peak, flows decreased and remained fairly low and consistent over the remainder of the study.

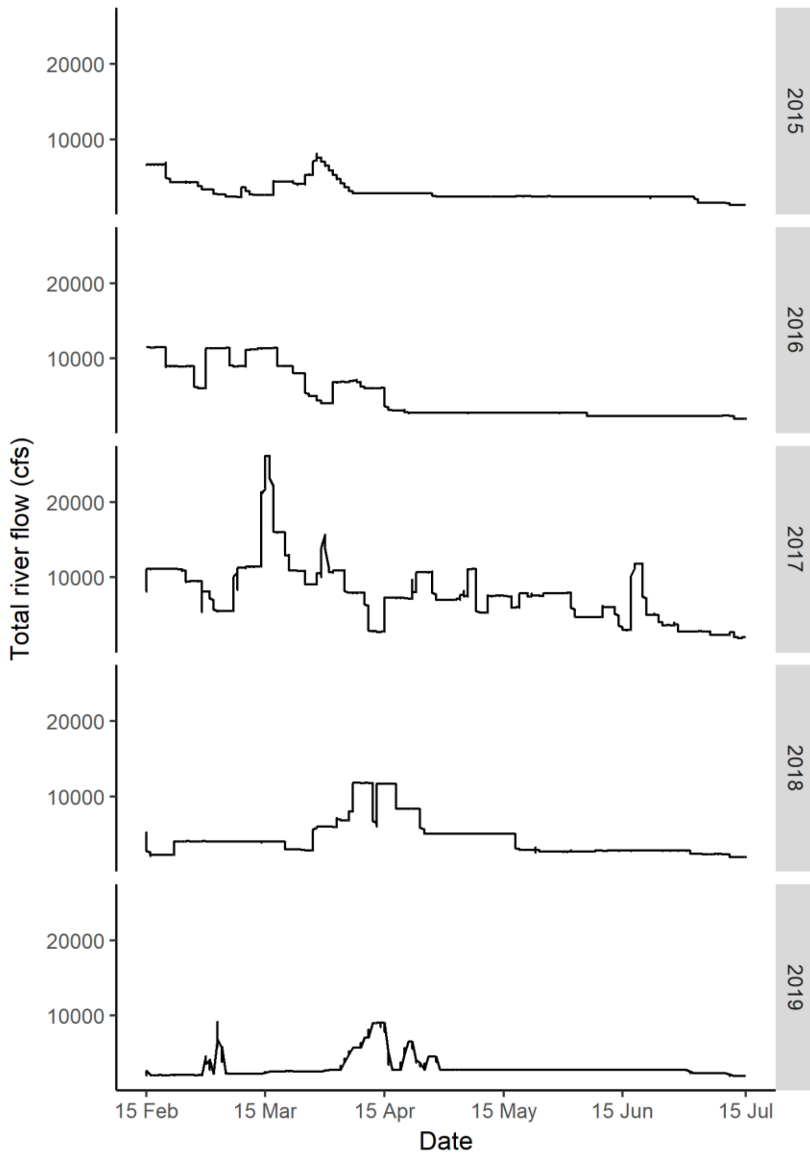

Figure 23. NF Lewis River discharge (cfs), measured downstream of Merwin Dam during steelhead monitoring across five study years.

Interannual comparisons indicate that, among study years, mean total NF Lewis River discharge in 2019 was lowest and had the lowest variability (Table 11). The trends in total NF Lewis River discharge over the study season in 2019 were most similar to those in 2015. Similar rates of steelhead entering the trap from the tailrace (P_{EE}) were also observed during these two years (2015 and 2019).

Table 11. Summary statistics for total NF Lewis River discharge (cfs) and winter steelhead core metrics (P_{EE} and ATE_{test}) across five study years. Only Non-Naïve fish are included in 2018 and 2019 to ensure core metrics are comparable with those from previous study years. Note that to estimate 95% confidence intervals (CI), 2018 and 2019 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)	*N*	*Raw P_{EE} (95% CI)*	*Raw ATE_{test} (95% CI)*
2015	3229 (±1924)	1060-11400	148	86% (79-90%)	61% (51-67%)
2016	4905 (±3372)	1260-11600	148	93% (87-96%)	73% (65-80%)
2017	7476 (±4337)	1190-26200	150	84% (77-90%)	76% (70-84%)
2018[1]	4556 (±2838)	1518-11900	73	99% (92-100%)	91% (83 – 96%)
2019[1]	3065 (±1397)	1940-9166	41	87% (88-97%)	85% (81-93%)

[1] Includes both trap Naïve and Non-Naïve release groups.

Objective 8: Evaluate the effects of unscheduled trap outages and fyke issue on *ATE and* T_i*, respectively*.

Description of unscheduled trap outages and fyke issue

During the 2019 steelhead monitoring season, the Merwin trap experienced unscheduled outages during March 5th-10th related to a mechanical failure of the lift and conveyance system. During this unscheduled trap outage, the fish elevator was not in operation, and the auxiliary water supply (AWS) was shut down, and the trap entrance bulkhead was closed. During the unscheduled outage, it was also discovered that one of the vertical bars within the fyke between ladder Pools 1 and 2 was missing. The fyke was repaired and conveyance system was put back in service on March 10th.

To understand the effects of these issues on steelhead core metrics and performance standards, below we present summaries of the numbers of fish affected by the unscheduled outage and adjusted metrics that have been computed excluding fish affected by the unscheduled outage and the fyke issue.

Summary of numbers of fish affected by unscheduled trap outages

A total of 22 fish were detected at either the Approach site or in the trap itself during the above described issues. Any fish detected at these sites could have been affected by either the trap entrance being closed (i.e., fish at the Approach site could have been prevented from entering the trap), the missing fyke post (i.e., fish inside the trap could not have been retained within the trap), or the hopper not being in operation (i.e., fish inside the trap could not have been collected by the hopper into the trap elevator). The following observations can be made about these 22 fish:

- Seven of 22 were Naïve fish; one of these seven was not re-captured;
- Seven of 22 were Non-Naïve fish; two of these seven were not re-captured; and
- Eight of 22 were Non-Naïve$_{PF}$ fish; two of these eight were not re-captured.

Core metrics and performance standards excluding fish affected by unscheduled trap outages

Core metrics for all fish that were not affected by the unscheduled outages are presented in Table 12 below and represent potentially achievable core metrics if the trap had not experienced unscheduled outages in 2019. Compared to core metrics presented for all fish (Table 3), ATE_{test} under this “hypothetical best-case scenario” (HBCS) increased by five percentage points each for Naïve and Non-Naïve fish and decreased by one percentage point for Non-Naïve$_{PF}$ fish resulting in ATE_{test} of 100%, 90%, and 79% for unaffected Naïve, Non-Naïve and Non-Naïve$_{PF}$ fish, respectively (Table 12).

Table 12. Summary of passage metrics for tagged steelhead approaching the tailrace of Merwin Dam during spring/summer 2019. Passage metrics are presented for tagged fish that were unaffected by the unscheduled trap outages that occurred during monitoring.

Metric	Unaffected Non-Naïve	Unaffected Naïve	Unaffected Non-Naïve$_{PF}$	Total
Tagged Fish (*N*)	34	16	35	85
Entered the Merwin tailrace (*M*)	31	15	33	79
Entered the Trap (*T*)	28	15	32	75
Captured (*C*)	28	15	26	69
Raw Trap Entrance Efficiency ($P_{EE} = \frac{T}{M}$)	90%	100%	97%	95%
Raw Collection Efficiency ($ATE_{test} = \frac{C}{M}$)	90%	100%	79%	87%
Raw Trap Ineffectiveness ($T_i = \frac{T-C}{T}$)	0%	0%	19%	8%

HBCS Total ATE:

To capture the different prior information for different release groups, we used a mixture prior (Bolstad 2007) that included one informed component based on 2018 results (weighted 50%) and one flat component based on a beta (1,1) (flat) prior (also weighted 50%). The mean of the Bayesian posterior ATE_{test} estimate for the Total number of fish that reached the tailrace under conditions associated with the above described HBCS (n = 79) was 89% (95% HDI = 82-94%). There was a greater than 99.9999% posterior probability that the true *ATE* value of the parent population for this group was less than 98%. That is, there was a less than 0.0001% posterior probability that the true *ATE* of the parent population met or exceeded the target.

HBCS Non-Naïve ATE:

Using an informed prior based on 2018 Non-Naïve fish results, the Bayesian posterior ATE_{test} estimate for the Non-Naïve fish that reached the tailrace under HBCS conditions (n = 31) was 90% (95% HDI = 83-95%). There was a 99.997% posterior probability that the true *ATE* value of the parent population for this group was less than 98%. That is, there was less than a 0.003% posterior probability that the true *ATE* of the parent population met or exceeded the target.

HBCS Naïve ATE:

Using an informed prior based on 2018 Naïve fish results, the Bayesian posterior ATE_{test} estimate for the Naïve fish that reached the tailrace under HBCS conditions (n = 16) was 97% (95% HDI = 89 – 99.9%). There was a 52% posterior probability that the true *ATE* value of the parent population for this group was less than 98%. That is, there was a 48% posterior probability that the true *ATE* of the parent population met or exceeded the target.

HBCS Non-Naïve$_{PF}$ ATE:

Using a flat prior, the Bayesian posterior ATE_{test} estimate for the Non-Naïve$_{PF}$ fish that reached the tailrace under HBCS conditions (n = 33) was 77% (95% HDI = 62-89%). There was a greater than 99.9999% posterior probability that the true *ATE* value of the parent population for this group was less than 98%. That is, there was less than 0.0001% posterior probability that the true *ATE* of the parent population met or exceeded the target.

Tailrace Residence Time Among Affected & Unaffected Fish

Performance standard compliance metrics for tailrace residence time are presented in Table 13 for fish that were affected and unaffected by the unscheduled trap outage. Affected fish had median tailrace residence time greater than 24 hours (Table 13), and thus did not achieve the performance standard of a median tailrace residence time less than 24 hours. In contrast, unaffected fish had median tailrace residence time less than 24 hours (Table 13), and thus achieved the performance standard of a median tailrace residence time less than 24 hours.

A Wilcoxon rank sum test comparing median tailrace residence time between affected and unaffected fish indicated that fish that were affected by unscheduled trap outages spent significantly more time in the tailrace compared to unaffected fish (W = 1433; $p < 0.001$). On average, fish affected by the unscheduled trap outage spent twice the number of hours in the tailrace compared to unaffected fish.

Table 13. Achieved performance standard compliance metrics for safe, timely, and effective passage of winter steelhead at Merwin Dam in 2019. Numbers of fish that entered the tailrace are presented (*M*) for each group. Metrics are also presented separately for fish affected and unaffected by unscheduled trap outages in 2019.

Unscheduled trap outage affected/unaffected	*M*	Median Tailrace Residence (range)	Percentage of Fish with Tailrace Residence Time > 168 hrs
Affected	*22*	*57 hrs (9.0-292.0 hrs)*	*2%*
Unaffected	*79*	*14 hrs (0.03-250.9 hrs)*	*5%*

Comparisons of residence times at individual detection sites in the tailrace and trap showed that fish affected by unscheduled trap outages spent more time holding at the Approach and Pool 4 sites and less time at the trap entrance compared to unaffected fish (Figure 24).

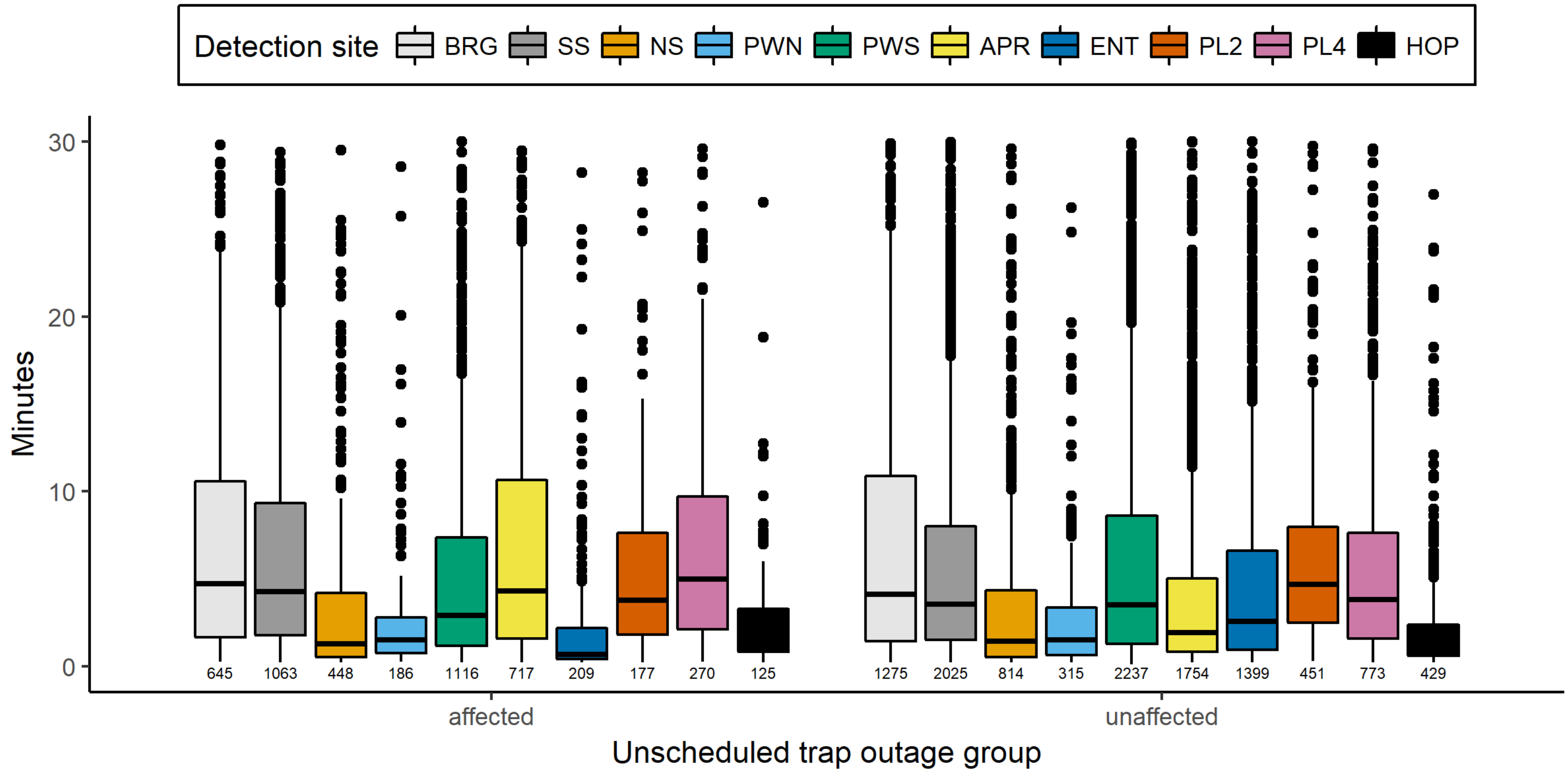

Figure 24. Median residence times by sites in the tailrace and trap. The figure is zoomed in to show the box and whisker plots, focusing on inter-quartile range, which excludes outliers (shown in closed circles) for residence times greater than 30 minutes from the figure. Data are separated by fish affected and unaffected by unscheduled trap outages in 2019. 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).

Evaluation of the effects of fyke repair on trap retention

Comparisons of the number of trap exit events and T_i for fish before the fyke was repaired versus after the fyke was repaired showed no clear differences. A summary of these results is presented below:

- 21 fish were detected inside the trap at locations past the fyke prior to the fyke being repaired (before March 10, 2019).
    - During this time there were 137 exit events (or 6.5 exit events per fish)
    - Two out of these 21 fish were never recaptured resulting in an estimated T_i of 9.5%
- 71 fish were detected inside the trap at locations past the fyke after the fyke was repaired (after March 10, 2019).
    - During this time there were 1,606 exit events (or 19.6 exit events per fish)
    - Seven out of these 71 fish were never recaptured resulting in an estimated T_i of 9.9%

DISCUSSION

Overview and Context

This report focuses on BWT hatchery winter steelhead collected and tracked during spring 2019, the fifth year of CFS reporting steelhead movements and passage metrics at Merwin Dam. Of note, this fifth study year compared core passage metrics and movements of three release groups:

- Fish captured at the Merwin Fish Collection Facility and subsequently released approximately 1 km downstream from the Merwin Dam tailrace (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, which thus presumably had no prior encounter with the trap (i.e., trap Naïve fish).
- Fish captured at the Merwin Fish Collection Facility and subsequently released approximately 29 km downstream from the Merwin Dam tailrace at Pekin Ferry (i.e., trap Non-Naïve$_{PF}$ fish)

All study years prior to 2018 used fish collected from the trap and released immediately (approximately 0.5 km) downstream of the tailrace (i.e., trap Non-Naïve fish) to assess passage efficiency as Merwin Dam. 2019 was the second study year to include a trap Naïve release group, to evaluate effects of prior capture at the Merwin Fish Collection Facility on passage success; 2018 steelhead and coho studies also included a Naïve release group, the results from which are available in separate reports (Drenner et al. 2018c; Drenner et al. 2019). Trap Non-Naïve$_{PF}$ fish were included to evaluate effects of release location on subsequent behaviors and re-capture rates of fish. This was the first study year to include a trap Non-Naïve$_{PF}$ release group of fish.

We hypothesized that both re-capture rates and migration behaviors were negatively affected by acute stress associated with tagging and handling. From this hypothesis, we predicted that Naïve fish, which experienced the least amount of handling, would perform better than Non-Naïve fish following release and would be more representative of the parent population of migrating steelhead in the Lewis River. Results from 2018 steelhead studies showed that Naïve fish had higher *ATE* (raw ATE_{test} = 100%) and exhibited more directed movements compared to Non-Naïve fish (Drenner et al. 2018c), which supported our predictions.

The focus on comparisons for the current study year was between Naïve and Non-Naïve fish, and among Naïve fish from different study years. However, a third group, the Non-Naïve$_{PF}$ fish, was introduced in 2019 to test for the effects of release location on behavior and re-capture rates. This effort was an attempt to disentangle the conflated effects of previous trap experience and release location, since, in addition to being captured within the river below the Merwin tailrace rather than at the trap as was the case for Non-Naïve fish, Naïve fish were also released further downstream compared to Non-Naïve fish, and thus had a greater distance to recover from acute stress prior to entering the tailrace. Comparisons between Naïve and Non-Naïve$_{PF}$ fish are thus included here to evaluate whether fish released further downstream after prior capture at the Merwin Fish Collection Facility pass with similar success rates as Naïve fish, which are logistically more challenging to capture as they are swimming freely within the river.

We hypothesized that Non-Naïve$_{PF}$ fish that reach the tailrace at Merwin Dam would have recovered from the acute stress imposed during transport and handling, and thus we predicted that these fish would behave similarly to Naïve fish. This prediction was based on our assumption that Non-Naïve fish released immediately below Merwin Dam may still be recovering from stress associated with handling and transport while they are in the tailrace due to the short distance (approximately 0.5 km) between their release location and the tailrace. Overall, the goal of including the different release groups was to generate the most realistic estimates of *ATE* at Merwin Dam.

Summary

Both raw and Bayesian posterior ATE_{test} values were below the 98% performance standard for all release groups in 2019, although this difference was statistically credible only for Non-Naïve and Non-Naïve$_{PF}$ fish. For the Naïve fish, we found an 18% 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. If considering a hypothetical best-case scenario that focuses only on Naïve fish attempting to pass when the Merwin trap was continuously operational, there was a 48% posterior probability that *ATE* was equal to or greater than the 98% performance standard.

Additionally, it should be noted that ATE_{test} values for Naïve fish during 2018 and 2019, the only years when naïve fish were included in the study, were the highest among all study species and groupings examined across all five years evaluating *ATE* at Merwin Dam. Significance or credibility of this difference among groups studied in different years has not yet been evaluated, but remains a topic of discussion. Confidence in concluding that the parent population of BWT hatchery winter steelhead in the NF Lewis River truly exhibited $ATE \geq ATE_{target}$, as could be drawn from evaluations based on the Naïve groups, is hampered by the relatively low sample size associated with these fish across 2018 and 2019, rather than the observed performance of individuals within these groups.

In addition to evaluating *ATE*, performance standards for tailrace residence time are also evaluated for fish attempting to pass Merwin Dam. Regulatory standards for tailrace residence time stipulate fish that enter the Merwin Dam tailrace must take less than 24 hours to pass, with no more than 5% of fish taking longer than 168 hours to pass. In 2019, median tailrace residence time for all Non-Naïve fish was approximately 29 hours, and 10% of fish took longer than 168 hours to pass. Both of these metrics exceed the regulatory standards for tailrace residence time. In contrast, median tailrace residence time for Naïve fish in 2019 was approximately 15 hours, and none of the Naïve fish took longer than 168 hours to pass. Thus, both of these metrics *achieved* the regulatory standard. As a note, Non-Naïve$_{PF}$ fish were somewhere in the middle, as they achieved the regulatory standard for median tailrace residence time of less than 24 hours but failed to achieve the standard of less than 5% of fish taking longer than 168 hours to pass. On average, both Naïve and Non-Naive$_{PF}$ fish spent approximately 40 fewer hours in the tailrace compared to Non-Naïve fish. Lower tailrace residence times of Naïve and Non-Naive$_{PF}$ fish suggest these fish exhibit more direct movements in the tailrace compared to Non-Naïve fish and provides evidence for behavioral differences among release groups.

Similar to previous study years, in 2019 steelhead located and entered the trap from the tailrace (P_{EE}) at higher rates than the rate at which they were captured (ATE_{test}). Both Naïve and Non-Naïve fish entered the trap from the tailrace at rates greater than 98% in 2019. Thus, under a hypothetical scenario where all fish that entered the trap were successfully captured, raw ATE_{test} in 2019 would have achieved the performance standard of 98% for both Naïve and Non-Naïve$_{PF}$ fish, but not for Non-Naïve fish, which only entered the trap at a rate of 87%. Retention in the trap, rather than attraction to the trap, thus still appears to be the primary factor limiting steelhead passage in 2019.

Initial studies in 2015 and 2016 showed that fish frequently exited the trap after entering from the tailrace (Stevens et al. 2016, Caldwell et al. 2017) and it was proposed that increasing retention of fish in the trap would contribute to increased passage efficiency. To achieve greater trap retention, a fyke was installed within the trap ladder prior to the 2017 tagging study. Since installation of this fyke, retention in the trap has been higher (T_i, has been lower) (Stevens et al. 2016, Caldwell et al. 2017, Drenner et al. 2018a, 2018b, 2018c, 2019). However, despite a reduction in T_i, fish continue to exit the trap after entering. In 2019, approximately 63% of fish that entered the trap later exited. It was proposed that low NF Lewis River stage that increases outflow in the trap ladder could decrease fyke effectiveness, because it increases the ability of fish to detect directionality of flow and locate the exit through the fyke. NF Lewis River flow was relatively low in 2019, which could have been associated with increased exit events in 2019 compared to 2018 (approximately 50% trap exit rate) and 2017 (approximately 25% exit rate), both of which were years with higher NF Lewis River flow.

Although a non-trivial proportion of steelhead may have exited the trap in 2019, steelhead appeared to be generally attracted to the tailrace and trap from downstream locations. Both Naïve and Non-Naïve$_{PF}$ release groups appeared to be more attracted to the trap once they entered the tailrace compared to Non-Naïve fish. 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 95% of the released fish (102/107) were d5etected entering the tailrace, with similar rates of released fish reaching the tailrace among release groups.
3) After entering the tailrace, steelhead most frequently took a path along the south side of the tailrace, where navigational cues presumably guide fish to the trap entrance.
4) All Naïve fish (P_{EE} = 100%) and almost all Non-Naïve$_{PF}$ fish (P_{EE} = 98%) that entered the tailrace subsequently entered the trap compared to P_{EE} = 87% for Non-Naïve fish.
5) Approximately 4% of released fish entered either the Cedar Creek or East Fork Lewis tributaries, suggesting low straying rates.
6) High proportions (95%) of Non-Naïve$_{PF}$ reached the tailrace, despite the release site being located approximately 29 km downstream from Merwin Dam.

Potential Explanatory Mechanisms

High attraction to the tailrace in 2019 could have been associated with relatively low NF Lewis River flow, as these were the lowest flows experienced over five study years for steelhead. When total NF Lewis River flow is low, the amount of attraction flow discharged from the tailrace into the NF Lewis River, which is held constant, would be higher relative to the NF Lewis River water being discharged from Merwin Dam. A greater ratio of attraction waters to NF Lewis River water might present more concentrated olfactory cues guiding hatchery origin steelhead to the tailrace. Indeed, the concentrations of olfactory cues in rivers during reproductive salmonid migrations has been shown to influence migration success and timing (Drenner et al. 2018d). Although purely observational, in years with lower NF Lewis River flow, such as 2018 and 2019, there appears to be higher *ATE* for steelhead (Drenner et al. 2018c), but other factors that differ among years and even within a monitoring season (e.g., dam operational, fish physiological/energetic condition) could also play a role. In addition, differences in passage among hatchery- and natural-origin individuals has not been explored here.

In 2019, there was some evidence that re-capture rates declined over the tagging and monitoring period, a trend that has not been consistently observed in each study year. A negative relationship between re-capture and release date was observed for all release groups in 2019, but this relationship was only significant for Non-Naïve fish. Declines in re-capture rates through the study season could be related to internal fish status, such as the amount of stored energy. In 2019, fish that were tagged earlier in the season had significantly higher muscle lipid content (i.e., stored energy) that would be available to support migration activities and could influence migration success. We did not find a significant relationship between individual fish muscle lipid content and probability of re-capture, but fish that were re-captured did tend to have higher muscle lipid content, which corresponds to results from 2018 (Drenner et al. 2018c) and provides some evidence that energetic state plays a role in influencing seasonal trends in re-capture rates. Overall, there are many environmental factors (e.g., NF Lewis River flow) and intrinsic organismal factors (e.g., physiological state) that could influence re-capture rates and behavior within a monitoring season and among years. Additional analyses are needed to better understand the effects these factors exert on steelhead behavior and passage efficiency.

Another factor in 2019 that could have influenced *ATE* was a period of unscheduled trap outages that occurred for approximately five successive days. At different times during unscheduled trap outages, the hopper was not in operation or the entrance to the trap was closed, which would have prevented fish from being captured or from entering the trap, respectively. Our analysis showed that a total of 22 fish were potentially impacted by the unscheduled trap outage (i.e., were either inside the trap or at the entrance to the trap at some point during the trap outage), but no single release group was affected more than others. Evidence for an overall effect of the unscheduled trap outage on migrating steelhead included:

1) More milling behaviors observed along the south side of the tailrace and near the trap entrance in 2019 compared to previous years.
2) Fish affected by the unscheduled trap outage spent twice as many hours on average in the tailrace and trap, compared to fish unaffected by the unscheduled trap outage. Median tailrace residence time for affected fish was greater than (i.e., did not achieve) the performance standard of 24 hours. However, median tailrace residence time for unaffected fish was less than (i.e., achieved) the performance standard of 24 hours.
3) Compared to fish unaffected by the unscheduled trap outage, affected fish spent more time holding at the Approach site to the trap entrance and in Pool 4 inside the trap providing evidence that fish were unable to enter the trap and were not being collected by the hopper, respectively, during the unscheduled trap outage.

4) When excluding fish affected by the unscheduled trap outage, ATE_{test} increased by 5 percentage points each for Naïve and Non-Naïve fish resulting in an ATE_{test} for unaffected fish of 100% and 90% for Naïve and Non-Naïve fish, respectively.

During the unscheduled trap outage, it was also discovered that a post was missing from the fyke installed at the entrance to Pool 2, which was subsequently repaired. Analysis examining the number of fish exit events and T_i before and after the fyke was repaired indicated there were no discernable effects of the missing fyke post on fish exiting the trap and on T_i. Although there didn't appear to be an effect of the missing fyke post on fish in 2019, it appeared that operational issues related to unscheduled trap outages did influence performance standards in 2019. If the trap had functioned throughout the 2019 season, Naïve fish might have achieved 100% ATE_{test} for the second season in a row.

Conclusions

Notably, Naïve fish again achieved the highest ATE_{test} (95%) among release groups in 2019. In addition, both Naïve and Non-Naïve$_{PF}$ fish had higher rates of entering the trap from the tailrace (i.e., P_{EE}) compared to Non-Naïve fish. Behavioral observations from 2019 could help explain the mechanisms behind observed differences in core metrics among release groups. To summarize, compared to Naïve and Non-Naïve$_{PF}$ fish, Non-Naïve fish:

1) Exhibited more milling behavior in the tailrace.
2) Visited twice as many sites, on average, despite Non-Naïve$_{PF}$ fish being released approximately 28 km further downstream from Merwin Dam compared to Non-Naïve fish.
3) Spent 40 additional hours, on average, in the tailrace.
4) Consumed the most energy after release, significantly more than Naïve fish. (*Interestingly, Non-Naïve and Non-Naïve$_{PF}$ fish consumed similar amounts of energy following release, again, despite Non-Naïve$_{PF}$ fish having to swim upstream an additional approximately 28 km to reach Merwin Dam.*)

Indeed, there is strong evidence to suggest that Non-Naïve fish were less direct in their migration (which likely resulted in greater energy use observed) compared to Naïve fish in 2019. These findings correspond with results from 2018 studies on steelhead (Drenner et al. 2018c). Somewhat surprisingly, Non-Naïve$_{PF}$ fish also seemingly out-performed Non-Naïve fish despite being subjected to additional handling associated with greater transport distance to their release site. Interestingly, although Non-Naïve$_{PF}$ fish appeared to be more direct in their migration compared to Non-Naïve fish, ATE_{test} was lower for Non-Naïve$_{PF}$ fish compared to Naïve fish. In addition, Non-Naïve$_{PF}$ fish entered the trap at higher rates (i.e., higher P_{EE}) compared to Non-Naïve fish and they spent a lot of time at the Hopper site inside the trap. Thus, lower ATE_{test} for Non-Naïve$_{PF}$ fish was due to lower retention in the trap. We originally suspected low trap retention for Non-Naïve$_{PF}$ fish might be associated with unscheduled trap outages or fyke issues disproportionally affecting Non-Naïve$_{PF}$ fish, but there was no evidence to support this.

Overall, our findings of less direct movements and lower ATE_{test} of Non-Naïve fish support our original hypothesis that Non-Naïve fish have not recovered fully from stress induced from trapping and handling due to their release location being close Merwin Dam. This is further supported by the finding that Non-Naïve$_{PF}$ fish showed signs of more direct migration while inside the tailrace despite this group being trapped at Merwin Dam and then transported further downstream.

Moreover, for a second year in a row, Naïve fish had the highest ATE_{test} among release groups. Our opinion is that Naïve fish are the most appropriate release group to represent the parent population of steelhead, and thus, for evaluating performance standards at Merwin Dam.

Although statistical confidence in estimates of ATE_{test} based on Naïve fish is relatively low, this is primarily the effect of low sample size, rather than performance of sampled fish. Sampling additional Naïve steelhead is the simplest and most effective way to address this shortcoming, although the maximum possible number of fish to include in a single year is limited by logistical and ecological constraints. Thus, one simple solution is to continue to monitor behaviors of Naïve steelhead, and to iteratively update findings by optimally leveraging previous data as informative priors.

Summary and Conclusions Recap

In 2019, a total of 107 steelhead were tagged including 41 Non-Naïve, 23 Naïve and 43 Non-Naïve$_{PF}$ fish.

Of the 41 Non-Naïve fish:

- 40 were detected at least once somewhere within the detection array;
- 39 entered the tailrace of Merwin Dam (*M*);
- 34 entered the trap (*C*), resulting in a raw P_{EE} ($\frac{C}{M}$) of 87%; and
- 33 were successfully captured (*T*), resulting in a raw ATE_{test} ($\frac{T}{M}$) of 85%.
- The Bayesian posterior estimate of ATE_{test} for Non-Naïve fish was 88% (95% HDI = 81-93%).

Of the 22 tagged Naïve fish:

- 22 were detected at least once somewhere within the detection array;
- 22 entered the tailrace of Merwin Dam (*M*);
- 22 entered the trap (*C*), resulting in a raw P_{EE} ($\frac{C}{M}$) of 100%; and
- 21 were successfully captured (*T*), resulting in a raw ATE_{test} ($\frac{T}{M}$) of 95%.
- The Bayesian posterior estimate of ATE_{test} for Naïve fish was 95% (95% HDI = 87 – 99%).

Of the 43 tagged Non-Naïve$_{PF}$ fish:

- 42 were detected at least once somewhere within the detection array;
- 41 entered the tailrace of Merwin Dam (*M*);
- 40 entered the trap (*C*), resulting in a raw P_{EE} ($\frac{C}{M}$) of 98%; and
- 32 were successfully captured (*T*), resulting in a raw ATE_{test} ($\frac{T}{M}$) of 78%.
- The Bayesian posterior estimate of ATE_{test} for Non-Naïve$_{PF}$ fish was 77% (95% HDI = 63-88%).

- In 2019, raw estimated adult trap efficiency (ATE_{test}) of the Merwin Dam Fish Trap Facility for all tagged steelhead was 84% (BCI 95% CI = 76-90%), 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 but did not achieve the regulatory standard of less than or equal to 5% of fish taking longer than 168 hours to pass.
- Naïve fish achieved performance standards for median tailrace residence time of less than or equal to 24 hours and for less than or equal to 5% of fish taking longer than 168 hours to pass.
- Estimated raw P_{EE} in 2019 for Naïve and Non-Naïve$_{PF}$ steelhead was 100% and 98%, respectively.
    - Thus, if all fish that entered the trap were successfully collected in 2019, raw ATE_{test} values would have achieved the performance standard for these two release groups.
- Steelhead were strongly attracted to the tailrace and trap in 2019 as evidenced by the following:
    - high numbers of tagged fish reaching the tailrace
    - high P_{EE}
    - low straying rates into tributaries
- We hypothesize that low NF Lewis River flows in 2019 could be associated with either or both of the following:
    - High attraction to the tailrace because of an increased ability to detect olfactory cues in attraction flows that are present in higher concentrations during lower NF Lewis River flows
    - Reduced retention in the trap because it creates greater flows in the trap ladder that provide fish a cue to locate the exit point through the fyke
- Unscheduled trap outages in 2019 were associated with increased amount of time fish spent in the tailrace and could have reduced passage efficiency.
- Estimated ATE_{test} differed significantly among release groups with Naïve fish having the highest estimated raw ATE_{test} of 95% (BCI 95% CI = 87-99%).
- Evidence suggested Naïve and Non-Naïve$_{PF}$ fish exhibited more direct movements towards the tailrace and trap.
    - Compared to these two release groups, Non-Naïve fish visited more sites, spent significantly more time in the tailrace, and used more energy.
- We propose that Naïve fish are the most appropriate release group to represent the parent population of steelhead, and thus, for evaluating performance standards at Merwin Dam.
- Naïve steelhead have achieved the performance standards for tailrace residence time in both study years to include this release group.
    - Using two years of data, there was a 18% probability that this group met or exceeded the 98% *ATE* target.

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APPENDIX A: SUPPLEMENTARY INFORMATION

A-1 Radio antennas technical information

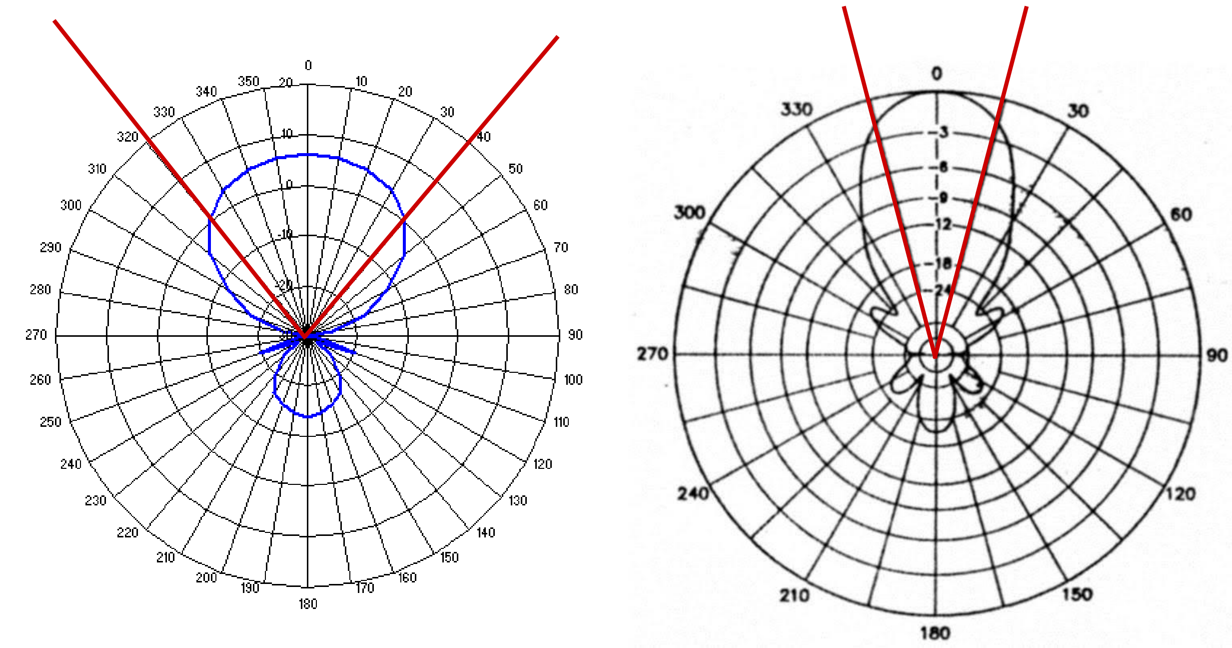
Five types of antennas were used during the 2018 Merwin *ATE* study: 3-, 6-, and 8-element aerial antennas, and underwater antennas. We describe the use and locations of these four antenna types below, with additional details provided in Table 2 above. *Three-element Yagi antennas* – Three-element antennas 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 (approximately 80^{o}) tag detection area, while the 8-element antenna has a longer but much narrower (approximately 30^{o}) tag detection area (Figure 25), 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 25. 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 6,095,999 detections in the raw data, and 3,823,195 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 1,424,148 of total detections (37%), 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 26), and the largest "peak" of noise detections came from the trap sites at the end of February (Figure 26). Adjustments to receivers in the trap were made in response to large amounts of noise detections, which declined thereafter. The receivers with the most noise hits were: LRH (36% of all noise detections), BLD (16.5%), and PL2 (14.9%). The large amount of noise at these sites is likely related to these sites being in areas where fish tend to congregate creating tag collisions that produce noise.

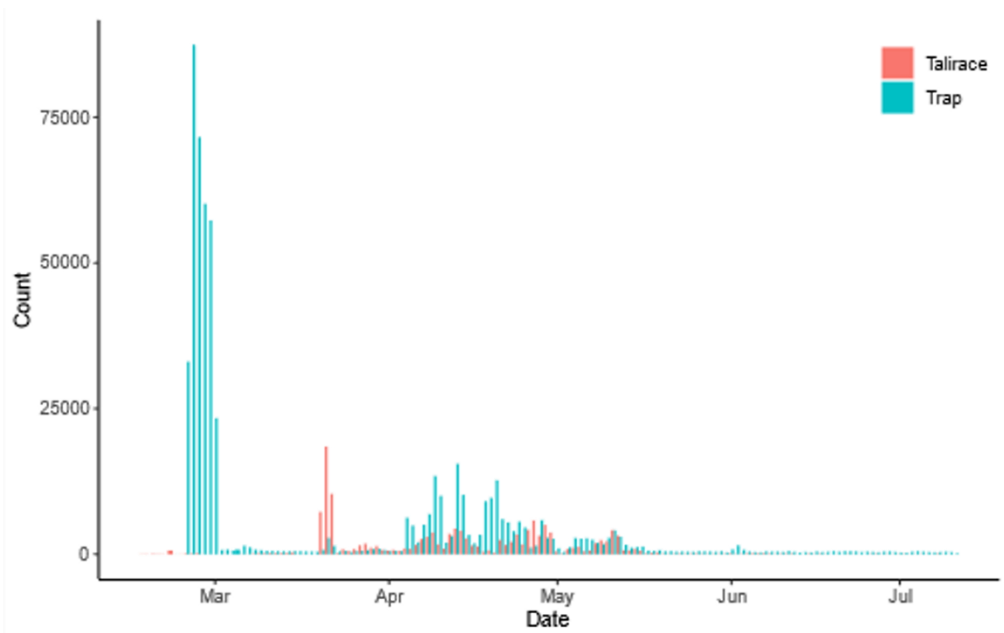


Figure 26. Total number of noise detections for tailrace (red) and trap (blue) receivers.

A-3 Individual Fish Summary Data

Table 14. Individual BWT winter steelhead characteristics and detection data summaries from all fish tagged and released in 2019. 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)	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
101	Naïve	M	67	3DD.003C01156C	3/27/2019 12:24	LRH	3/27/2019 12:29	HOP	4/11/2019 11:25	HOP	4/11/2019 11:26	Y
119	Naïve	M	74	3DD.003BC95F8D	2/25/2019 12:15	LRH	2/25/2019 12:25	TRP	4/13/2019 19:43	TRP	4/13/2019 19:43	Y
251	Non-Naïve	F	74	3DD.003D47BCEC	3/15/2019 10:16	BLD	3/15/2019 18:00	TRP	4/2/2019 11:59	TRP	4/2/2019 11:59	Y
253	Naïve	M	69	3DD.003BC95FD6	3/5/2019 10:41	BLD	3/5/2019 10:47	TRP	3/28/2019 17:40	TRP	3/28/2019 17:40	Y
254	Non-Naïve	F	88	3DD.003D47BCE8	3/15/2019 10:16	BLD	3/15/2019 10:34	TRP	3/18/2019 21:04	TRP	3/18/2019 21:04	Y
255	Non-Naïve$_{PF}$	F	78	3DD.003D2BE665	4/25/2019 10:50	LRM	4/25/2019 12:31	HOP	5/1/2019 12:34	BLD	5/23/2019 19:49	N
257	Non-Naïve	F	77	3DD.003D47BCF7	3/15/2019 10:16	BLU	3/15/2019 18:51	TRP	5/4/2019 13:39	TRP	5/4/2019 13:39	Y
258	Naïve	M	74	3DD.003D2BE6B0	4/11/2019 9:20	BLD	4/11/2019 14:04	TRP	4/15/2019 10:36	TRP	4/15/2019 10:36	Y
259	Naïve	M	66	3DD.003C01157F	3/20/2019 9:33	BLD	3/23/2019 1:29	TRP	4/12/2019 8:46	TRP	4/12/2019 8:46	Y
260	Non-Naïve	F	77	3DD.003D47BCC4	3/12/2019 10:50	BLD	3/12/2019 10:56	TRP	4/19/2019 4:14	TRP	4/19/2019 4:14	Y
261	Naïve	M	68	3DD.003C0115B7	3/27/2019 13:29	LRH	4/6/2019 14:13	TRP	4/8/2019 14:13	TRP	4/8/2019 14:13	Y
263	Non-Naïve	M	67	3DD.003D47BCAA	3/12/2019 10:50	BLD	3/12/2019 15:55	TRP	4/15/2019 12:44	TRP	4/15/2019 12:44	Y
266	Non-Naïve	F	69	3DD.003D47BCC2	3/15/2019 10:16	BLD	3/15/2019 10:24	TRP	4/11/2019 19:29	TRP	4/11/2019 19:29	Y
267	Naïve	M	70	3DD.003C0115BE	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Y
269	Non-Naïve	F	78	3DD.003D47BCCC	3/18/2019 9:00	BLU	3/21/2019 16:29	TRP	4/8/2019 17:36	TRP	4/8/2019 17:36	Y
270	Naïve	M	54	3DD.003D28BE695	4/16/2019 12:19	BLD	4/17/2019 22:08	TRP	4/18/2019 18:30	TRP	4/18/2019 18:30	Y
272	Non-Naïve	M	84	3DD.003D47BCD3	3/18/2019 9:00	BLD	3/18/2019 14:56	HOP	4/11/2019 9:53	BLU	4/30/2019 3:18	Y
273	Naïve	M	74	3DD.003C01156E	3/13/2019 12:57	BBL	4/7/2019 1:18	TRP	4/14/2019 4:27	TRP	4/14/2019 4:27	Y
275	Non-Naïve	F	79	3DD.003D47BD03	3/18/2019 9:00	BLD	3/18/2019 9:07	TRP	4/18/2019 22:50	TRP	4/18/2019 22:50	Y
278	Non-Naïve$_{PF}$	M	79	3DD.003.D47BCA6	3/25/2019 9:49	BBL	3/25/2019 19:54	BBL	3/25/2019 19:54	BBL	3/25/2019 22:19	Y
279	Naïve	M	92	3DD.003D2BE6A3	4/17/2019 9:02	BLD	4/17/2019 11:45	TRP	5/30/2019 21:31	TRP	5/30/2019 21:31	Y
281	Non-Naïve$_{PF}$	M	68	3DD.003.D47BCC7	3/25/2019 9:49	BBL	3/25/2019 18:54	TRP	4/22/2019 15:36	TRP	4/22/2019 15:36	Y
282	Naïve	F	79	3DD.003D2BE6AF	4/9/2019 11:43	LRH	4/9/2019 11:57	TRP	4/17/2019 23:16	TRP	4/17/2019 23:16	Y

Fish code	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
284	Non-Naïve$_{PF}$	M	83	3DD.003.D47BCA5	3/25/2019 9:49	BBL	3/25/2019 21:18	LRH	4/16/2019 20:48	LRH	4/17/2019 12:59	Y
285	Non-Naïve$_{PF}$	M	70	3DD.003D47BCF4	3/11/2019 10:17	LRM	3/11/2019 10:22	TRP	4/4/2019 14:29	TRP	4/4/2019 14:29	Y
287	Non-Naïve$_{PF}$	M	70	3DD.003.D47BCBA	3/25/2019 9:49	BBL	3/25/2019 21:02	TRP	4/12/2019 9:43	TRP	4/12/2019 9:43	Y
288	Non-Naïve$_{PF}$	M	88	3DD.003D47BCE2	3/11/2019 10:17	LRM	3/11/2019 10:22	HOP	4/5/2019 13:43	PL4	4/11/2019 10:56	Y
290	Non-Naïve	F	64	3DD.003D47BCFC	3/18/2019 9:00	BLD	3/18/2019 9:06	TRP	4/11/2019 11:31	TRP	4/11/2019 11:31	Y
293	Non-Naïve$_{PF}$	M	72	3DD.003.D47BCC9	3/25/2019 9:49	BBL	3/25/2019 23:44	TRP	4/11/2019 19:29	TRP	4/11/2019 19:29	Y
294	Naïve	M	62	3DD.003C01159D	3/20/2019 9:54	LRH	4/12/2019 8:58	TRP	4/12/2019 19:58	TRP	4/12/2019 19:58	Y
296	Non-Naïve$_{PF}$	M	70	3DD.003BC95F8A	3/25/2019 9:49	BBL	3/25/2019 17:57	TRP	4/2/2019 16:00	TRP	4/2/2019 16:00	Y
297	Naïve	F	76	3DD.003BC95F8E	3/5/2019 13:20	BLU	4/4/2019 14:23	TRP	4/10/2019 17:10	TRP	4/10/2019 17:10	Y
299	Non-Naïve$_{PF}$	M	86	3DD.003BC95FDB	3/25/2019 9:49	BBL	3/26/2019 14:21	TRP	4/11/2019 12:17	TRP	4/11/2019 12:17	Y
300	Naïve	F	63	3DD.003BC95FE0	3/7/2019 10:01	LRH	3/7/2019 19:16	TRP	4/11/2019 14:29	TRP	4/11/2019 14:29	Y
302	Non-Naïve$_{PF}$	F	76	3DD.003BC95FD3	3/25/2019 9:49	BBL	3/25/2019 18:26	TRP	4/11/2019 14:18	TRP	4/11/2019 14:18	Y
303	Naïve	F	66	3DD.003C01159C	3/27/2019 13:35	BLD	4/5/2019 13:08	TRP	4/26/2019 8:51	TRP	4/26/2019 8:51	Y
305	Non-Naïve$_{PF}$	F	78	3DD.003BC95FBD	3/25/2019 9:49	BBL	3/25/2019 20:34	TRP	4/10/2019 18:15	TRP	4/10/2019 18:15	Y
306	Naïve	M	88	3DD.003C011FA3	3/26/2019 10:19	LRH	3/29/2019 17:31	TRP	4/10/2019 18:15	TRP	4/10/2019 18:15	Y
308	Non-Naïve$_{PF}$	M	73	3DD.003BC95FCE	3/25/2019 9:49	BBL	3/25/2019 23:20	TRP	4/21/2019 22:02	TRP	4/21/2019 22:02	Y
311	Non-Naïve	F	71	3DD.003D27A6AC	4/18/2019 10:12	BLU	4/18/2019 15:56	TRP	5/1/2019 17:13	TRP	5/1/2019 17:13	Y
312	Non-Naïve	F	82	3DD.003D27FADB	4/18/2019 10:12	N/A	N/A	N/A	N/A	N/A	N/A	N
313	Non-Naïve$_{PF}$	F	67	3DD.003D27B0E8	4/19/2019 10:50	LRM	4/19/2019 13:24	HOP	5/1/2019 20:30	LRM	5/24/2019 6:47	N
314	Non-Naïve$_{PF}$	F	81	3DD.003D27859F	4/19/2019 10:50	BBL	4/19/2019 18:07	HOP	4/22/2019 13:20	LRM	5/28/2019 2:06	N
315	Non-Naïve$_{PF}$	F	91	3DD.003D2794D5	4/19/2019 10:50	BBL	4/19/2019 16:43	HOP	4/22/2019 20:55	HOP	5/29/2019 12:29	Y
316	Non-Naïve$_{PF}$	M	71	3DD.003D279456	4/19/2019 10:50	BBL	4/19/2019 17:12	TRP	4/22/2019 16:23	TRP	4/22/2019 16:23	Y
317	Non-Naïve$_{PF}$	M	62	3DD.003D279561	4/19/2019 10:50	BBL	4/28/2019 15:11	TRP	5/2/2019 16:21	TRP	5/2/2019 16:21	Y
318	Non-Naïve$_{PF}$	M	71	3DD.003D27A011	4/19/2019 10:50	BBL	4/19/2019 17:46	HOP	4/27/2019 17:42	LRM	5/29/2019 6:58	N
319	Non-Naïve	F	72	3DD.003D2BE613	4/25/2019 9:37	BLD	4/25/2019 9:42	BLU	4/30/2019 15:44	LRM	5/10/2019 11:44	N
320	Non-Naïve	M	81	3DD.003D2BE611	4/25/2019 9:37	BLD	4/25/2019 9:49	BLD	4/25/2019 9:49	BBL	5/19/2019 19:42	N
321	Non-Naïve	F	76	3DD.003D2BE61F	4/25/2019 9:37	BLD	4/25/2019 9:47	TRP	4/26/2019 0:13	TRP	4/26/2019 0:13	Y

Fish code	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
322	Non-Naïve$_{PF}$	F	80	3DD.003D2798E3	5/1/2019 9:20	BBL	5/1/2019 23:42	TRP	5/14/2019 12:16	TRP	5/14/2019 12:16	Y
324	Non-Naïve$_{PF}$	F	65	3DD.003D2BE60C	4/25/2019 10:50	BBL	4/27/2019 22:05	TRP	5/13/2019 21:10	TRP	5/13/2019 21:10	Y
325	Non-Naïve$_{PF}$	F	66	3DD.003D27FDB4	5/1/2019 9:20	LRM	5/1/2019 10:02	APR	5/7/2019 13:20	LRM	5/18/2019 6:49	N
326	Non-Naïve$_{PF}$	F	65	3DD.003D27C0DC	5/1/2019 9:20	BBL	5/2/2019 15:46	TRP	5/10/2019 3:28	TRP	5/10/2019 3:28	Y
361	Non-Naïve	M	70	3DD.003BC95FE2	3/26/2019 8:50	BLD	3/26/2019 9:16	TRP	4/11/2019 18:49	TRP	4/11/2019 18:49	Y
362	Non-Naïve	M	64	3DD.003BC95FB8	3/26/2019 8:50	BLU	4/7/2019 0:39	TRP	4/12/2019 11:41	TRP	4/12/2019 11:41	Y
363	Non-Naïve	M	75	3DD.003BC95FA4	3/26/2019 8:50	BLD	3/26/2019 9:48	TRP	4/15/2019 11:39	TRP	4/15/2019 11:39	Y
364	Non-Naïve	M	68	3DD.003BC95FD7	3/26/2019 8:50	BLD	3/26/2019 8:56	TRP	4/13/2019 19:45	TRP	4/13/2019 19:45	Y
365	Naïve	M	54	3DD.003C011568	3/27/2019 9:00	LRH	3/27/2019 9:22	TRP	4/8/2019 17:36	TRP	4/8/2019 17:36	Y
366	Naïve	M	71	3DD.003D2BE6C8	4/17/2019 14:20	BLD	4/18/2019 2:35	TRP	4/18/2019 8:33	TRP	4/18/2019 8:33	Y
368	Non-Naïve	M	70	3DD.003BC95F8B	3/26/2019 8:50	LRH	3/28/2019 2:43	TRP	4/25/2019 18:49	TRP	4/25/2019 18:49	Y
369	Naïve	M	69	3DD.003C0115BD	3/28/2019 14:20	BLD	3/28/2019 14:25	HOP	4/13/2019 11:40	LRM	5/12/2019 6:17	N
371	Naïve	F	77	3DD.003C0115AE	3/27/2019 10:02	BLD	3/28/2019 4:16	TRP	5/14/2019 2:35	TRP	5/14/2019 2:35	Y
372	Naïve	M	69	3DD.003D2BE6C5	4/4/2019 12:20	LRH	4/4/2019 17:00	BLD	4/10/2019 13:32	LRM	5/22/2019 8:49	N
373	Naïve	M	85	3DD.003C0115AC	3/27/2019 10:31	BLU	3/31/2019 8:35	TRP	4/2/2019 18:38	TRP	4/2/2019 18:38	Y
374	Non-Naïve	M	85	3DD.003BC95FEC	4/1/2019 9:17	BLD	4/1/2019 9:39	TRP	5/31/2019 20:54	TRP	5/31/2019 20:54	Y
375	Non-Naïve	F	83	3DD.003BC95F9E	4/1/2019 9:17	BLD	4/1/2019 9:25	TRP	4/25/2019 19:54	TRP	4/25/2019 19:54	Y
376	Non-Naïve	M	85	3DD.003BC95F9B	4/1/2019 9:17	BLD	4/1/2019 9:22	TRP	4/12/2019 16:44	TRP	4/12/2019 16:44	Y
377	Non-Naïve	M	73	3DD.003BC95FD2	4/1/2019 9:17	BLU	4/6/2019 9:03	TRP	4/11/2019 16:29	TRP	4/11/2019 16:29	Y
378	Non-Naïve	M	59	3DD.003BC95FE7	4/1/2019 9:17	BLD	4/1/2019 9:31	TRP	5/10/2019 17:26	TRP	5/10/2019 17:26	Y
379	Non-Naïve	F	79	3DD.003BC95FB1	4/1/2019 9:17	BLU	4/3/2019 16:14	APR	4/5/2019 8:20	LRM	5/1/2019 21:04	N
380	Non-Naïve	M	91	3DD.003BC95FAA	4/1/2019 9:17	BLD	4/1/2019 9:29	APR	4/6/2019 14:22	BLU	5/1/2019 6:44	N
381	Non-Naïve$_{PF}$	F	80	3DD.003BC95FCD	4/2/2019 9:28	BBL	4/3/2019 1:26	TRP	5/11/2019 8:45	TRP	5/11/2019 8:45	Y
382	Non-Naïve$_{PF}$	M	69	3DD.003BC95FC5	4/2/2019 9:28	BBL	4/2/2019 20:26	HOP	4/13/2019 10:29	LRM	6/2/2019 6:09	N
383	Non-Naïve$_{PF}$	M	69	3DD.003BC95F97	4/2/2019 9:28	BBL	4/2/2019 21:45	HOP	4/15/2019 12:03	LRH	6/12/2019 11:09	N
384	Non-Naïve$_{PF}$	F	83	3DD.003BC95FC3	4/2/2019 9:28	BBL	4/3/2019 3:02	TRP	4/11/2019 22:47	TRP	4/11/2019 22:47	Y
385	Non-Naïve$_{PF}$	M	87	3DD.003BC95FB6	4/2/2019 9:28	BBL	4/2/2019 23:03	PL4	4/7/2019 13:20	LRM	6/2/2019 5:32	N

Fish code	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
386	Non-Naïve$_{PF}$	M	60	3DD.003BC95F9F	4/2/2019 9:28	BBL	4/2/2019 18:10	PL4	4/12/2019 13:57	BBL	4/27/2019 21:50	N
387	Non-Naïve$_{PF}$	F	65	3DD.003D2BE705	4/8/2019 12:27	EFL	4/10/2019 15:19	TRP	4/13/2019 18:38	TRP	4/13/2019 18:38	Y
388	Non-Naïve$_{PF}$	M	69	3DD.003D2BE6F7	4/8/2019 12:27	BLD	4/9/2019 19:44	TRP	4/11/2019 20:23	TRP	4/11/2019 20:23	Y
389	Non-Naïve$_{PF}$	F	72	3DD.003D2BE6FF	4/8/2019 12:27	LRM	4/8/2019 13:19	TRP	4/15/2019 15:11	TRP	4/15/2019 15:11	Y
390	Non-Naïve$_{PF}$	F	67	3DD.003D2BE72F	4/8/2019 12:27	BBL	4/8/2019 20:30	TRP	4/11/2019 17:21	TRP	4/11/2019 17:21	Y
391	Non-Naïve$_{PF}$	F	70	3DD.003D2BE715	4/8/2019 12:27	LRM	4/8/2019 13:21	TRP	4/26/2019 14:14	TRP	4/26/2019 14:14	Y
392	Non-Naïve$_{PF}$	F	76	3DD.003D2BE6F1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N
397	Naïve	F	76	3DD.003D2BE6A5	4/4/2019 12:50	LRH	4/6/2019 15:05	TRP	4/8/2019 17:36	TRP	4/8/2019 17:36	Y
399	Non-Naïve$_{PF}$	M	67	3DD.003D2BE6EC	4/8/2019 12:27	LRM	4/9/2019 19:14	TRP	4/12/2019 16:44	TRP	4/12/2019 16:44	Y
400	Non-Naïve$_{PF}$	F	63	3DD.003D2BE710	4/8/2019 12:27	BBL	4/9/2019 12:53	TRP	4/20/2019 19:04	TRP	4/20/2019 19:04	Y
401	Non-Naïve$_{PF}$	M	92	3DD.003D2BE716	4/8/2019 12:27	LRM	4/8/2019 20:46	BLU	4/21/2019 19:40	LRM	4/30/2019 23:27	N
402	Non-Naïve$_{PF}$	F	80	3DD.003D2BE702	4/8/2019 12:27	EFL	4/8/2019 18:33	TRP	4/22/2019 20:45	TRP	4/22/2019 20:45	Y
403	Non-Naïve	F	64	3DD.003D2784CE	4/16/2019 9:02	BLD	4/19/2019 15:29	TRP	4/26/2019 14:15	TRP	4/26/2019 14:15	Y
404	Non-Naïve	M	64	3DD.003D2786D9	4/16/2019 9:02	BLD	4/16/2019 9:08	TRP	4/20/2019 20:08	TRP	4/20/2019 20:08	Y
405	Non-Naïve$_{PF}$	M	70	3DD.003D278FE4	4/19/2019 10:50	BBL	4/19/2019 15:08	TRP	4/26/2019 15:19	TRP	4/26/2019 15:19	Y
406	Non-Naïve	F	81	3DD.003D28003B	4/18/2019 10:12	BLU	4/18/2019 16:14	TRP	4/28/2019 10:29	TRP	4/28/2019 10:29	Y
407	Non-Naïve	M	70	3DD.003D27AA0B	4/18/2019 10:12	BLD	4/18/2019 10:17	TRP	5/8/2019 16:54	TRP	5/8/2019 16:54	Y
408	Non-Naïve	F	79	3DD.003D279E16	4/18/2019 10:12	BLD	4/20/2019 14:25	TRP	4/21/2019 22:03	TRP	4/21/2019 22:03	Y
409	Non-Naïve	F	68	3DD.003D2794C5	4/18/2019 10:12	BLD	4/18/2019 10:17	TRP	5/8/2019 22:18	TRP	5/8/2019 22:18	Y
410	Non-Naïve$_{PF}$	F	63	3DD.003D27A7A8	4/19/2019 10:50	BBL	4/19/2019 17:11	TRP	4/26/2019 13:11	TRP	4/26/2019 13:11	Y
411	Non-Naïve$_{PF}$	F	65	3DD.003D2785FA	4/19/2019 10:50	BBL	4/19/2019 16:43	TRP	4/28/2019 10:28	TRP	4/28/2019 10:28	Y
412	Non-Naïve$_{PF}$	F	65	3DD.003D280264	4/19/2019 10:50	BBL	4/19/2019 17:04	TRP	5/9/2019 10:18	TRP	5/9/2019 10:18	Y
413	Non-Naïve	F	65	3DD.003D278959	4/16/2019 9:02	BLD	4/16/2019 9:07	APR	4/28/2019 9:49	BRG	4/28/2019 14:43	N
414	Non-Naïve	F	76	3DD.003D278A79	4/16/2019 9:02	BLD	4/16/2019 9:17	APR	4/17/2019 8:20	LRM	5/12/2019 6:08	N
415	Non-Naïve	M	57	3DD.003D27B8A8	4/16/2019 9:02	BLD	4/16/2019 9:07	BRG	5/6/2019 1:39	LRM	5/29/2019 19:04	N
416	Non-Naïve	M	91	3DD.003D27939C	4/16/2019 9:02	BLD	4/16/2019 9:18	TRP	4/18/2019 16:21	TRP	4/18/2019 16:21	Y
417	Non-Naïve	F	60	3DD.003D279C52	4/16/2019 9:02	BLU	4/16/2019 9:14	TRP	4/18/2019 19:36	TRP	4/18/2019 19:36	Y

Fish code	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
418	Non-Naïve	M	64	3DD.003D278638	4/16/2019 9:02	BLD	4/16/2019 9:07	TRP	5/12/2019 17:05	TRP	5/12/2019 17:05	Y
419	Non-Naïve	F	67	3DD.003D27FE1B	4/16/2019 9:02	BLD	4/16/2019 9:09	TRP	4/19/2019 15:15	TRP	4/19/2019 15:15	Y
420	Non-Naïve	F	81	3DD.003D27859C	4/16/2019 9:02	BLD	4/16/2019 9:07	HOP	4/27/2019 15:49	HOP	4/27/2019 16:03	Y

2082

A-4 Tailrace Residence Time Summary Table

Table 15. 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 and 2019, metrics are also presented separately for release groups.

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%*
2019	winter steelhead	102	22.6 hrs (0.03-292.0 hrs)	7%
	Naïve	*22*	*15.4 hrs (1.4-74.0 hrs)*	*0%*
	Non-Naïve	*39*	*28.9 hrs (0.03-292.0 hrs)*	*10%*
	Non-Naïve$_{PF}$	*41*	*17.8 hrs (1.1-250.9 hrs)*	*7%*

APPENDIX E

SPAWN TIMING, DISTRIBUTION AND ABUNDANCE OF TRANSPORTED FISHES – 2019 FINAL REPORT

Meridian Environmental, Inc.

Environmental Sciences
Regulatory Planning
Project Management

Memorandum

To: Erik Lesko, PacifiCorp, Chris Karchesky, PacifiCorp

From: Jason Shappart, Senior Fisheries Scientist

Date: February 28, 2020

Re: NF Lewis River upstream of Swift Dam – 2019 Salmon Spawning Survey Results

Introduction

Coho Salmon spawning surveys were conducted from October 1, 2019 through January 10, 2020 by Meridian Environmental, Inc. (Meridian) 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 (NF) Lewis River upstream of Swift Dam. Due to the very low number of spring Chinook transported upstream in 2019, spawning surveys specifically for spring Chinook in September were not included in PacifiCorp's 2019 authorized scope of work. However, some spring Chinook were observed spawning during October. Therefore, spring Chinook spawning observations are also presented.

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 approximately 33 percent 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 2019, the year-2 panel received its third visit since first being surveyed in 2013 and resurveyed in 2016. This memorandum summarizes salmon spawning survey results for the year-2 panel conducted from October 1, 2019 to January 10, 2020. The 2013 and 2016 results are also discussed, where possible, to illustrate potential changes in transported anadromous fish spawn timing, distribution and abundance over time.

Survey Conditions

The USGS North Fork Lewis River above Muddy River gage[1] approximates general flow patterns relative to median conditions throughout the NF Lewis River basin during the survey season (Figure 1). Daily mean flows in 2019 were at about median flow levels through the first half of October, followed by a relatively brief rise due to a storm event in the second half of October. However, after this storm event, flows receded well below median flow levels through mid-December due to unusually dry conditions. Large storm events in late-December resulted in very high flows through the rest of December (Figure 1).

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

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Flow conditions during the majority of the 2019 survey season were generally much lower than flows during the 2013 and 2016 survey seasons (Figure 1). Small tributary streams within the year-2 panel were either totally dry or too low to allow upstream migration of spawning salmon until the second half of October, including reservoir tributaries such as S10, S15, S20, Diamond, Range, and Drift creeks, and many of the small tributaries throughout the upper basin (Pepper, Spencer, M1, P3, and P7 creeks). Many of these streams returned to very low flows after the late-October storm event, until flows rose again in mid-December. Low flows likely precluded Coho access into these small streams during a substantial portion of the survey season. Of note is that Swift Reservoir was also very low during this time period due to lack of precipitation, and substrate gradient in the drawdown zone (in addition to low stream flows) may have hindered upstream migration into some reservoir tributaries to an unknown degree.

Flows over about 1,000 cfs (Lewis River above Muddy River gage) are considered unsafe for conducting spawning surveys via kayak on the upper NF Lewis River mainstem and visibility is also generally greatly reduced. Flows were generally well below 1,000 cfs during the survey season, which allowed for several kayak surveys to be conducted. However, flows over 1,000 cfs limited kayak surveys during the second half of December. Snow and closed gates limited upper Muddy River and Pine Creek watershed surveys after late-November. High flows and substantial snow during late-December rendered most streams unsurveyable for the remainder of the survey season.

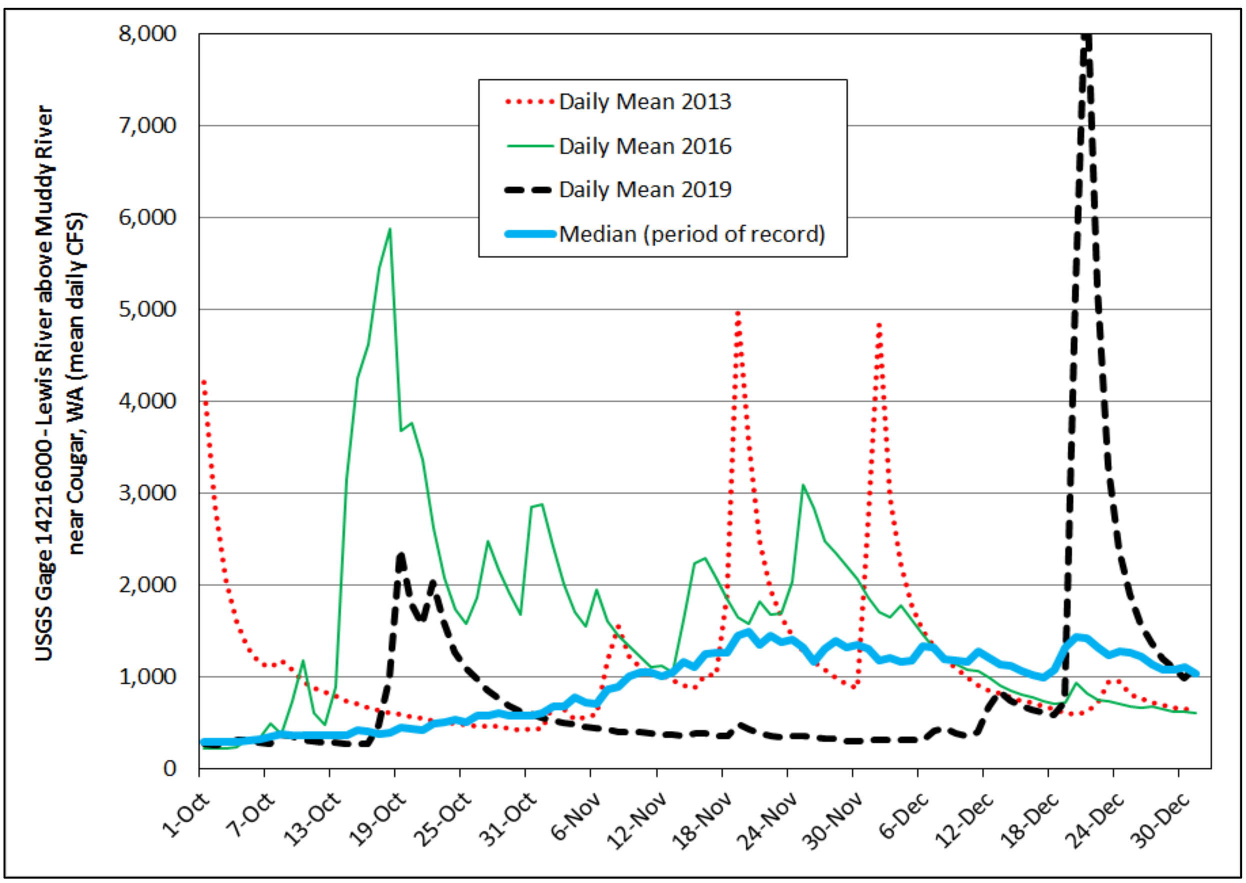

Figure 1. USGS North Fork Lewis River above Muddy River Gage average daily flow (cfs) October through December 2019.

Methods

Field survey methods followed those described in the revised monitoring and evaluation plan (PacifiCorp and Cowlitz PUD 2017) with no deviations. In some prior years, low reservoir levels prevented launching a conventional power boat at the Swift Boat Ramp to conduct reservoir tributary surveys when the reservoir is lower than the end of the boat ramp. This year Meridian employed a canoe equipped with an outboard motor to access tributary reaches. The canoe could be launched without needing a boat ramp.

Note that in 2019 all surveys were conducted by Meridian biologists. In 2016, surveys were conducted by the same Meridian biologist crew as well as PacifiCorp biologists. In 2013 kayak surveys of the mainstem NF Lewis River were conducted by Meridian biologists, but all other surveys were conducted by Washington Department of Fish and Wildlife crews.

Results

Spring Chinook and Coho Transported Upstream

A total of 12 adult female Chinook were transported upstream to spawn during 2019. All of the spring Chinook were transported upstream by the end of July 2019.

A total of 2,373 adult female Coho were transported upstream to spawn during 2019, and of these 2,368 could have potentially been observed during the survey period (i.e., transported upstream prior to the last survey on January 10, 2020). A total of 3,104 and 3,311 adult female Coho were available for observation during the October through December survey time period during 2013 and 2016 (respectively).

Spring Chinook Spawning Observations

A total of six redds observed during early October were attributed to spring Chinook spawning. Three of these redds were large and looked to be a few weeks old when first observed in early October, which were probably constructed in September. One redd counted on October 9, 2019 had a live Chinook adult on the redd. Two other redds were within reaches where live Chinook or carcasses were observed on the same survey. Live Coho spawners had not yet been observed near these same reaches at the time these redds attributed to Chinook were first observed. Four of the Chinook redds were counted in the Muddy River watershed (redds observed in Clear and Clearwater creeks, and the Muddy River mainstem) and two of the Chinook redds were counted in the mainstem NF Lewis River (Table 1). Spring Chinook have been counted in prior years in these same streams. Consistent with prior years' results, 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 P3, P7 and P8 creeks during all of September and October for Bull Trout spawning surveys. Rush Creek was also surveyed weekly in September and October for Bull Trout surveys and no spring Chinook were observed.

Table 1. Spring Chinook spawning observation summary (October 2019).

	2019 Spring Chinook				
	# Reaches in Panel	% Reaches Surveyed Sep	% Reaches Surveyed Oct	# Chinook (live + dead)	# of Redds
Muddy River Watershed	**43**	**0%**	**93%**	**3**	**4**
Clear Creek	14[a]	0%	86%	0	1
Clearwater Creek	7	0%	100%	2	2
M1 Creek	2	0%	100%	0	0
Muddy River mainstem	15	0%	100%	1	1
Smith Creek	5[b]	0%	80%	0	0
NF Lewis Watershed	**19**	**0%**	**100%**	**1**	**2**
NF Lewis River mainstem	14	0%	100%	1	2
Pepper Creek	2	0%	100%	0	0
Rush Creek	2	100%	100%	0	0
Spencer Creek	1	0%	100%	0	0
Pine Creek Watershed	**18**	**100%**	**100%**	**0**	**0**
P3 Creek	2	100%	100%	0	0
P7 Creek	2	100%	100%	0	0
P8 Creek	5	100%	100%	0	0
Pine Creek mainstem	9	100%	100%	0	0
Swift Reservoir Watershed	**8**	**0%**	**100%**	**0**	**0**
Diamond Creek	1	0%	100%	0	0
Drift Creek	1	0%	100%	0	0
Forest Camp Creek	1	0%	100%	0	0
Range Creek	1	0%	100%	0	0
S10 Creek	1	0%	100%	0	0
S15 Creek	1	0%	100%	0	0
S20 Creek	1	0%	100%	0	0
Swift Creek	1	0%	100%	0	0
Grand Total	**88**	**23%**	**97%**	**4**	**6**

[a]Two of 14 reaches were not accessible due to steep inaccessible canyon slopes.
[b]The most upstream reach is not logistically feasible to survey.

Coho Redd Counts

A total of 182 Coho redds were counted during the 2019 survey season (Table 2). Coho primarily spawned in the mainstem NF Lewis River and Muddy River watershed. Coho redds were also observed throughout many Swift Reservoir tributaries (Table 2). Several Coho redds were also observed in the Pine Creek watershed (Table 2). Of note is that no redds were observed in S20 Creek, where historically many Coho redds have been found in the last few years. In addition, relatively few redds were counted in the Swift Reservoir tributaries in total. This is likely due to low flows and low reservoir levels during the majority of the 2019 Coho spawning season that likely limited Coho access.

A new stream (Forest Camp Creek) was added to the sample frame in 2019 after residents of the surrounding recreational community reported Coho spawning observations to

PacifiCorp. Forest Camp Creek enters Swift Reservoir upstream of the Swift Forest Camp boat ramp area and the accessible reach is about 900 feet in length (Figure 2). The stream is small and low flows probably limited fish access until mid-December. Several Coho spawners and redds were observed in this reach in December 2019 after stream flows increased. It appears that the culvert under FR-90 is an upstream migration barrier as no Coho or redds were observed during spot checks of about 1,000 feet of excellent potential spawning habitat upstream of the culvert on the same days when Coho and redds were observed throughout the reach downstream of the culvert.

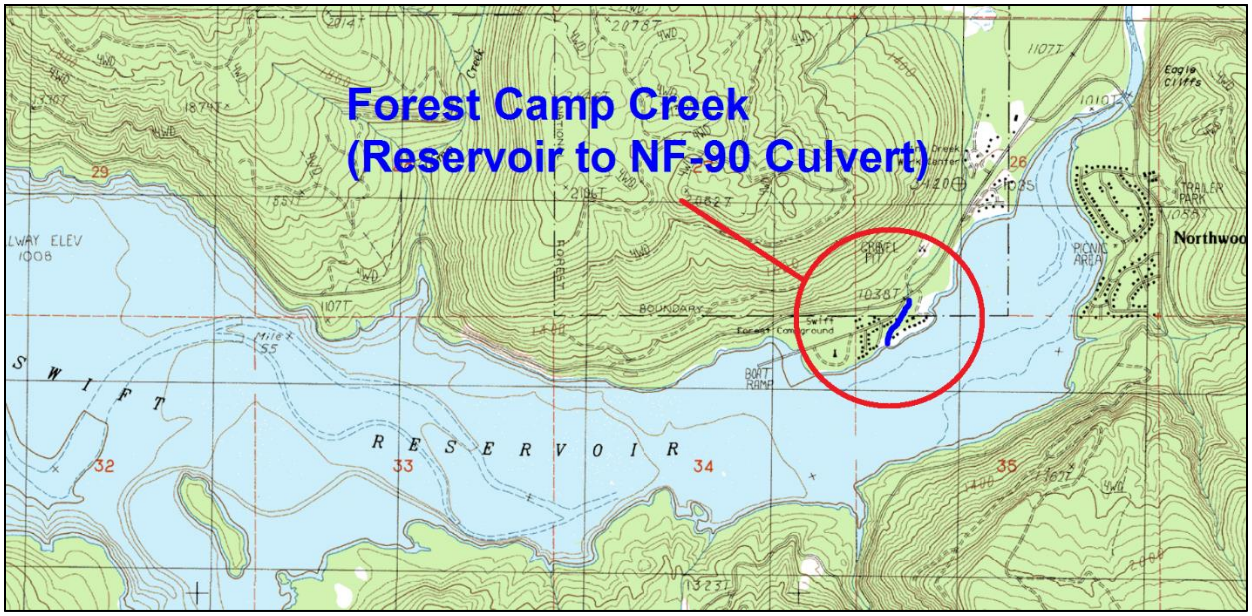

Figure 2. Forest Camp Creek reach added to the sample frame in 2019.

In 2019 and 2013, over 70 percent of all redds counted were observed in the NF Lewis River mainstem and Muddy River watersheds combined. However, in 2016 only 29 percent of all redds counted were observed in these two areas; 62 percent of redds were counted in the reservoir tributaries in 2016. Higher flows during the majority of the Coho spawning period may account for the greater proportion of Coho that spawned in Swift Reservoir tributaries in 2016 compared to 2019 and 2013 (see Figure 1). In addition, higher flows in 2016 may have contributed to more survey reaches being occupied by Coho in 2016 (52%) compared to 2019 (40%) and 2013 (47%); see Table 2.

Table 2. Coho spawning survey summary results (2019).

	2019 Coho								2016 Coho			2013 Coho		
	# Reaches in Panel	% Reaches Surveyed Sep	% Reaches Surveyed Oct	% Reaches Surveyed Nov	% Reaches Surveyed Dec	# of Redds	# Coho (live + dead)	% Surveyed Reaches Occupied[e]	# of Redds	# Coho (live + dead)	% Surveyed Reaches Occupied[e]	# of Redds	# Coho (live + dead)	% Surveyed Reaches Occupied[e]
Muddy River Watershed	**43**	**0%**	**93%**	**79%[c]**	**42%[c]**	**55**	**6**	**43%**	**19**	**76**	**43%**	**31**	**54**	**46%**
Clear Creek	14[a]	0%	86%	86%	64%	31	2	83%	15	62	67%	25	40	100%
Clearwater Creek	7	0%	100%	100%	0%	9	0	29%	1	3	43%	5	5	43%
M1 Creek	2	0%	100%	100%	0%	0	0	0%	0	4	50%	added in 2016		
Muddy River mainstem	15	0%	100%	60%	60%	15	0	27%	3	5	27%	1	9	20%
Smith Creek	5[b]	0%	80%	80%	0%	0	4	25%	0	2	25%	0	0	0%
NF Lewis Watershed	**19**	**0%**	**100%**	**100%**	**63%[d]**	**79**	**11**	**42%**	**29**	**14**	**63%**	**98**	**159**	**65%**
NF Lewis River mainstem	14	0%	100%	100%	50%	79	11	57%	29	3	50%	95	159	71%
Pepper Creek	2	0%	100%	100%	100%	0	0	0%	0	2	100%	0	0	0%
Rush Creek	2	0%	100%	100%	100%	0	0	0%	0	0	0%	0	0	0%
Spencer Creek	1	0%	100%	100%	100%	0	0	0%	0	9	100%	3	0	100%
Pine Creek Watershed	**18**	**0%**	**100%**	**100%**	**78%[c]**	**13**	**5**	**17%**	**16**	**2**	**50%**	**0**	**0**	**0%**
P3 Creek	2	0%	100%	100%	100%	0	0	50%	not surveyed[f]			0	0	0%
P7 Creek	2	0%	100%	100%	100%	5	3	0%	0	0	0%	0	0	0%
P8 Creek	5	0%	100%	100%	20%	0	0	0%	0	0	0%	0	0	0%
Pine Creek mainstem	9	0%	100%	100%	100%	8	2	22%	16	2	80%	0	0	0%
Swift Reservoir Watershed	**8**	**0%**	**100%**	**100%**	**100%**	**35**	**108**	**75%**	**103**	**74**	**100%**	**40**	**157**	**83%**
Diamond Creek	1	0%	100%	100%	100%	3	21	100%	34	5	100%	6	34	100%
Drift Creek	1	0%	100%	100%	100%	2	1	100%	16	24	100%	14	91	100%
Forest Camp Creek	1	0%	100%	100%	100%	10	30	100%	added in 2019			added in 2019		
Range Creek	1	0%	100%	100%	100%	5	6	100%	24	11	100%	13	16	100%
S10 Creek	1	0%	100%	100%	100%	0	0	0%	5	8	100%	0	0	0%
S15 Creek	1	0%	100%	100%	100%	0	0	0%	5	5	100%	0	1	100%
S20 Creek	1	0%	100%	100%	100%	0	6	100%	1	11	100%	added in 2016		
Swift Creek	1	0%	100%	100%	100%	15	44	100%	18	10	100%	7	15	100%
Grand Total	**88**	**0%**	**97%**	**90%**	**59%**	**182**	**130**	**40%**	**167**	**166**	**52%**	**169**	**370**	**47%**

Table 2 Notes:
[a]Two of 14 reaches were not accessible due to steep inaccessible canyon slopes.
[b]The most upstream reach is not logistically feasible to survey.
[c]Seasonally closed roads and snow limited access to reaches.
[d]Higher flows in December limited some kayak survey reaches due to safety.
[e]A reach was determined to be occupied if a live Coho, Coho carcass, or Coho redd was counted within the reach.
[f]PacifiCorp crew inadvertently surveyed the year-1 panel reach 173 instead of the year-2 panel reaches 174 and 176.

Spawn Timing

As surveys for spring Chinook were not conducted in September 2019, Chinook spawn timing could not be assessed. Spring Chinook spawning observations in October are presented in Table 2 for informational purposes and to illustrate the observed end of Chinook spawning in relation to the start of Coho spawning.

Table 3. Key spawn timing observations (2019).

Timing Parameter	Chinook	Coho
1st live holder observed	none	10/4/19
1st live spawner observed	10/9/19	10/14/19
1st occupied redd observed	10/9/19	10/14/19
1st carcass observed	10/3/19	10/29/19
Last live holder observed	none	12/30/19
Last live spawner observed	10/9/19	1/8/2020
Last carcass observed	10/4/19	1/8/2020

The first Coho redds observed with active Coho spawners present were counted in the NF Lewis River mainstem on October 14, 2019. A total of one new redd and no live Coho or carcasses were observed in Swift Creek on the last survey on January 10, 2020, and three live Coho and no new redds were observed in Forest Camp Creek on January 8, 2020. Based on weekly Coho redd counts and Coho upstream transport timing (Figure 2), the spawn timing of Coho was bimodal. Early-Coho peak spawning was observed during the second half October associated with an increase in stream flows followed by more protracted late-Coho spawning throughout December and early-January associated with increased flows (Figure 2).

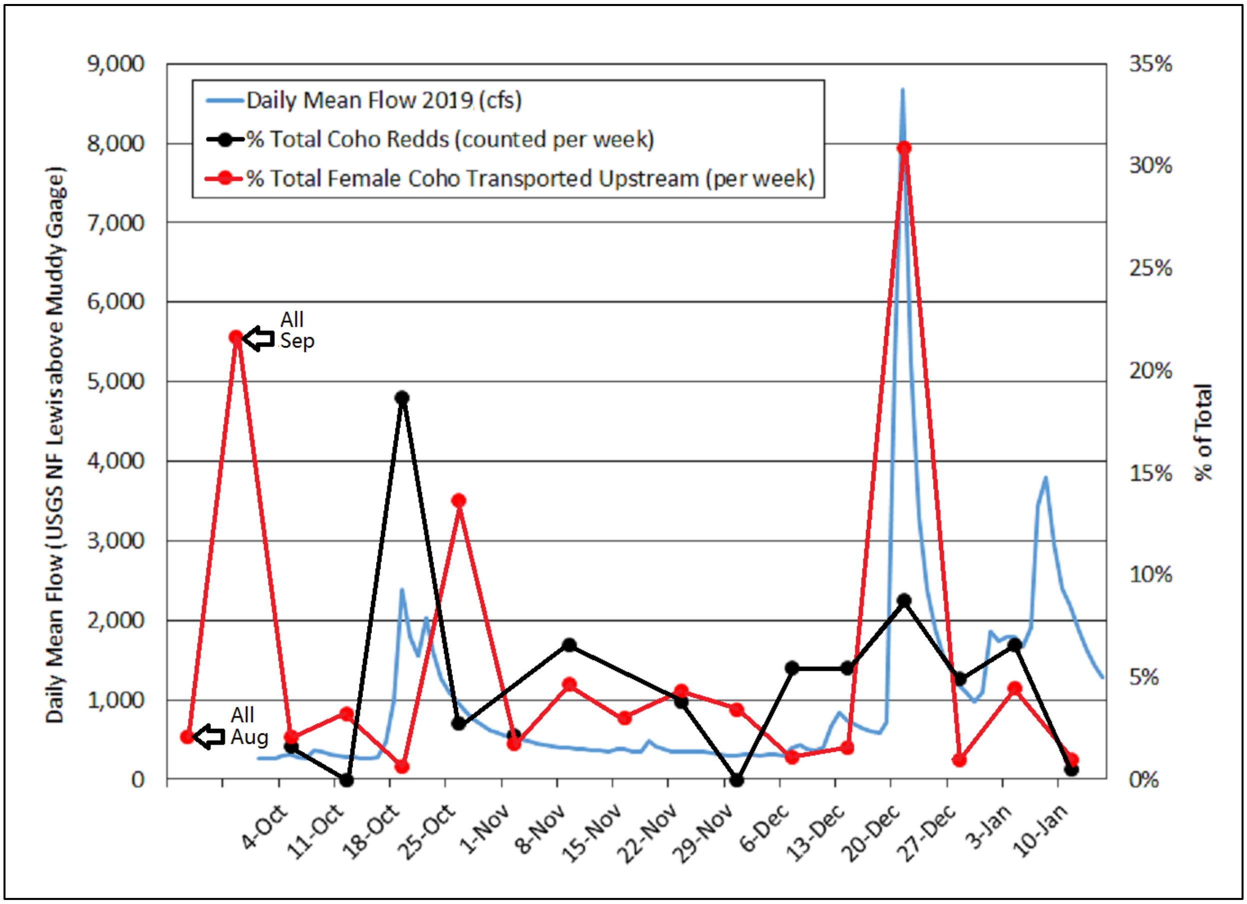

Figure 2. Coho redd count timing vs. adult female Coho transport timing vs flow (2019).

Estimate of Total Redds

Redd counts were used to make estimates of total redds by watershed (Starcevich 2020). 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 4. 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 5.

Note that spring Chinook redd estimates are based on redd surveys conducted only in October 2019. September surveys were not part of the authorized scope of work. However, stream flows were generally low (at or below median conditions) during 2019. Previous spring Chinook spawning surveys upstream of Swift Dam suggest many redds may be visible for more than two weeks. Therefore, spawning surveys conducted the first week in October likely had a high probability of detecting Chinook redds constructed in September. The Chinook redd estimates also assume that redds attributed to Chinook were not actually made by early-Coho spawning in September.

Table 4. 2019 total spring Chinook redd estimates.

	2019 Total Redd Estimate	95% Confidence Interval
Muddy River Watershed	15	5 to 25
NF Lewis River Watershed	8	0 to 14
Pine Creek Watershed	0	0
Swift Reservoir Watershed	0	0
Grand Total	**10**	**35**

Table 5. 2019 total Coho redd estimates.

	2019 Total Redd Estimate	95% Confidence Interval
Muddy River Watershed	387	183 to 662
NF Lewis River Watershed	558	59 to 1,180
Pine Creek Watershed	86	0 to 190
Swift Reservoir Watershed	249	83 to 453
Grand Total	**1,280**	**607 to 2,171**

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 1.90 (bootstrap 95 percent confidence interval of 0.86 to 2.91) as the proportion of transported female Chinook that spawned in 2019 (Starcevich 2020), which is within the range of estimates made over the previous 5-year period (Table 6).

Table 6. Estimates of the proportion of spawning Chinook females by year.

	Estimated Proportion of Spawning Female Coho	95% Confidence Interval
2019	1.90	0.86 to 2.91
2018	2.17	0.29 to 4.16
2017	1.03	0.56 to 1.50
2016	none transported upstream	
2015	none transported upstream	
2014	none transported upstream	

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 0.54 (bootstrap 95 percent confidence interval of 0.26 to 0.91) as the proportion of transported female Coho that spawned in 2019 (Starcevich 2020), which is within the range of estimates made over the previous 5-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
2019	0.54	0.26 to 0.91
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 2019 spawned (similar to previous years when Chinook were transported upstream to spawn). Proportions of successful female spawners of 1.0 (or greater) suggest that all transported females spawned (assuming one 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 one redd on average. It is also possible that some Chinook may residualize in Swift Reservoir to adulthood to spawn, which could also contribute to proportions greater than 1.0 (i.e., if the actual number of females spawners is greater than the number of transported anadromous females).

Similar to previous years, Chinook appear to have distributed throughout the Muddy River watershed (Clearwater Creek and Muddy River mainstem) and NF Lewis River mainstem based on 2019 live Chinook and carcass observations in early-October (see Table 1). 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, 2018, and 2019 when weekly surveys were conducted over the entire mainstem during the Chinook spawning season for the purpose of Bull Trout spawning surveys.

Though Coho redds were well distributed through the entire stream network upstream of Swift Dam, unusually low flows in the reservoir tributaries in combination with low reservoir conditions through the majority of the Coho spawning season likely limited spawning habitat for early and late-Coho, which have been shown to widely use the reservoir tributaries for spawning in previous years. Furthermore, spawning success may have been reduced by Coho selecting to spawn in the drawdown zone due to low stream flow and low reservoir conditions. Though not specifically quantified, some Coho were observed spawning in the drawdown zones of reservoir tributaries and the mainstem NF Lewis River. The sample frame only covers the stream network of available habitat upstream of the reservoir full pool elevation. Therefore, an assumption inherent to the sample design is that if Coho spawn below the full pool elevation within the drawdown zone, these redds are not counted, and therefore are treated as unsuccessful spawning events.

It is important to note that over 30 percent of Coho were transported upstream in late-December after seasonally closed roads and snow limited access to a large portion of the Muddy River watershed. This spawning survey was originally 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 somewhat problematic due to inherent survey limitations such as seasonally closed roads, typical snow accumulation, and typical large storms that decrease stream visibility in the late-fall and early-winter.

References

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